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FLUORESCENT LIGHTING AT ALL SAINTS CHURCH, BRIGHTON.

The church is lit throughout by 5 ft. fluorescent lamps. The illustration shows the lighting of the choir, the lamps being concealed behind the arch. Illumination of the altar is emphasised by the addition of two floodlights.

Electrical Progress and Development

Contributed by Members of the Technical Staffs of the Works and Research Laboratories of the Company.

INTRODUCTION.

DURING the past year the dominant theme has been recovery. In this great national effort the electrical industry is playing an outstanding part. The year's target for the export of electrical goods was set at 184 per cent above 1938; the Company's present monthly rate of shipment is at an average of 247 per cent above that of 1938. A great amount of electrical equipment has also been supplied for home use.

The equipment of the Meaford Power Station has been completed. New orders from the British Electricity Authority include generating plant for Huddersfield, Doncaster and Woolwich.

Industrial equipment in course of construction includes geared turbo-alternator sets for the Steel Company of Wales and for South Africa and a number of turbo-compressors and turbo-blowers for home and overseas customers.

The whole of the coal handling plant at the new Kingston Power Station was built at the Erith Works.

A new range of heavy metalclad switchgear has been introduced, the first order for which comprises 34 units for substations in Birmingham.

Typical of detailed improvements in mercury arc rectifiers is the provision of additional anodes enabling a single grid-controlled rectifier to operate as a complete unit for variable speed D.C. drives.

An order from Sociedade Estoril for motor coaches and a locomotive is the first ever to be placed with a British firm by a Portuguese railway. All the electrical equipment, to the value of approximately £1,000,000, is being supplied for forty electric locomotives for the South African Railways.

Electronic control is being ever more widely used in industry. Recent applications include the control of a rotary printing press and of a number of 100,000 lb. drawbenches.

Active research on telecommunications continues. A new and larger H.F. transmitter has been developed; the frequency range of compact V.H.F. equipment has been extended to include the new band allocated to business radio.

Production facilities are continually being improved. The High Power Testing Laboratory is being re-equipped and extended, and a new Turbo-alternator Works, costing over £1,000,000, is being erected at Witton Works which will be capable of building generators up to ratings of 100,000 kW.

POWER EQUIPMENT.

Turbo-Generators and Compressors.

During the past year an appreciable amount of plant has been supplied to augment the generating capacity of the British Electricity Authority. There have been put into commission a third 30,000 kW set at Woolwich Power Station and a second 30,000 kW set at Newport, in addition to the four 30,000 kW sets in the Meaford Power Station, the installation of which has now been completed.

A turbo-compressor of 20,000 cu. ft. per min. capacity at 80 lbs. per sq. in. supplied to Rand Mines, Ltd., for Blyvooruitzicht has now been in service for some time. This machine embodies the latest design features and contains nine stages with six stages of intercooling as compared with three stages of intercooling on the older turbo-compressors. Operating results confirm that the more effective cooling has resulted in substantially improved efficiency.

Plant for Home Use.

New orders from the British Electricity Authority include one 30,000 kW turbo-alternator set for Huddersfield, two 30,000 kW sets for Doncaster and a further 30,000 kW set for Woolwich. The last-named machine is the fourth to be installed at the Woolwich Power Station and differs from the three previous sets,

which were designed for 400 lbs. per sq. in. steam pressure and 800 degs. F., in that in accordance with the recent Statutory Rule and Order, it is to operate with a steam pressure of 600 lbs. per sq. in. and 850 degs. F.

Among the orders for equipment for industrial use is a 2,000 kW double pass-out, back pressure, geared turbo-alternator for the Steel Company of Wales. The turbine is required to supply process steam at 165 lbs. per sq. in. and also steam for feed water heating at 30 lbs. per sq. in. It will be provided with special governing enabling the turbine to operate under pressure control while the alternator is connected to the Grid or under speed control when disconnected from the Grid. This set will be installed in the same power station for which three turbo-blowers and two 8,000 kW mixed pressure sets are already in course of construction.

For Skinningrove Iron Co., Ltd., there is on order a turbo-blower capable of handling 65,000 cu. ft. of air a minute against a pressure of 20 lbs. per sq. in. The blower will be driven by a high-pressure steam turbine.

EQUIPMENT FOR EXPORT.

Many new orders have been received from South Africa during the period under review, amongst which are two 2,000 kW geared turbo-alternator sets for Vryheid Colliery and a third turbo-blower for the South African Iron and Steel Industrial Corporation. This blower is capable of dealing with 68,400 cu. ft. of air a minute against a pressure of 20 lbs. per sq. in. and is driven by a 7,000 h.p. 2-pole turbo-type motor at 3,000 r.p.m. For the Anglo-American Corporation there is a turbo-compressor driven by a high-pressure steam turbine designed to handle 15,000 cu. ft. of free air a minute against a pressure of 90 lbs. per sq. in., and six turbo-compressors, electrically driven through gearing, capable of handling 20,000 cu. ft. of free air per minute against a pressure of 100 lbs. per sq. in. and provided with six stages of intercooling. These latest orders bring the number of turbo-compressors installed or on order for this corporation to a total of sixteen.

An order for a third 7,500 kW turbo-alternator has been received from the State Electricity

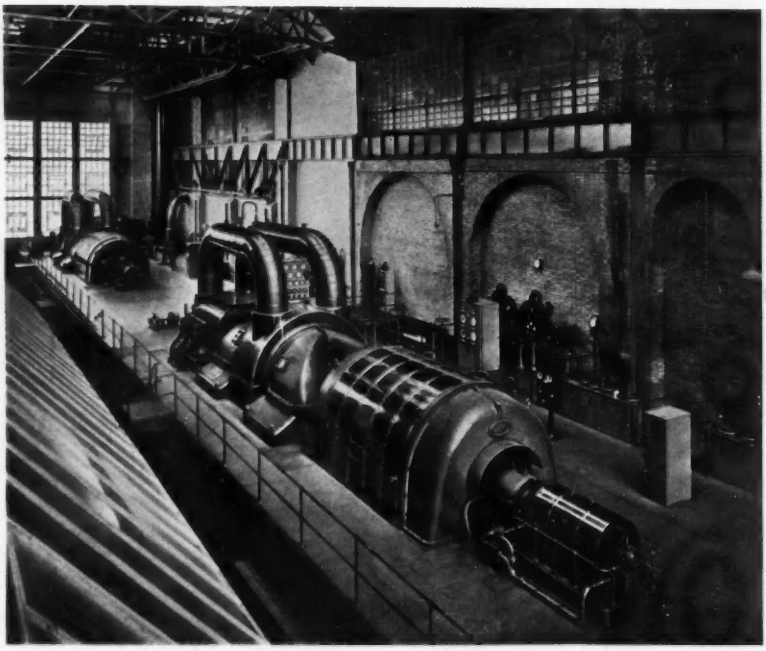


Fig. 1.—Two 37,500 kVA 6·2 kV and 11 kV turbo-alternators in the East Power Station at Newport, Monmouthshire.

Commission of Queensland, Australia. Geared turbo-alternator sets are in hand for the Iraq Spinning and Weaving Company and for Raipur Central Province, India.

Of the equipment which is being supplied to various European countries, four machines were delivered during the year. These comprise two 25,000 kW pass-out turbo-alternators and two 12,000 kW double pass-out turbo-alternator sets.

In taking tests on site, obviously all the usual electrical measurements and temperature measurements can be made with almost the same facility as on the Works test bed. However, owing to the fact that in the power station the alternator is coupled to the steam turbine, the accurate measurement of the various losses by input methods is extremely difficult and other methods of loss measurement are desirable.

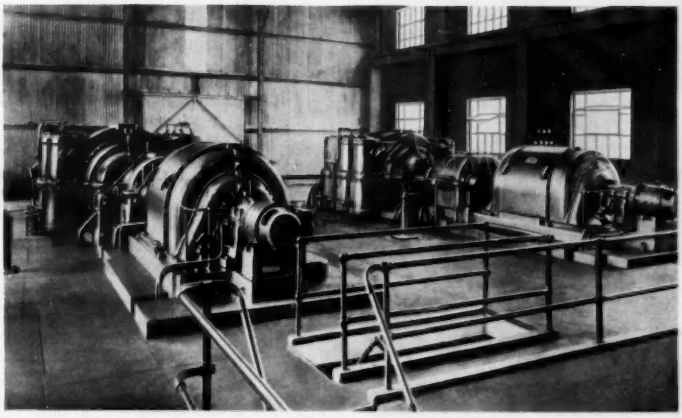


Fig. 2.—Two 3,500 h.p. turbo-compressors in the Central Compressing Station of Vlakfontein Gold Mining Co., Ltd., South Africa.

SPECIAL SITE TESTS ON TURBO-ALTERNATORS.

From time to time large turbo-alternators have to be installed on site without undergoing the normal routine Works tests. The most obvious example of this is when the machine is actually built on site, but other circumstances occasionally make this course desirable. In a recent case of this nature special arrangements were made that, during the reduced demand of the summer months, site tests should be carried out to determine whether the machine complied with the guarantees of the order.

The series of site tests which were made covered, firstly, the usual light load Works tests including open circuit and short circuit conditions. Afterwards advantage was taken of the site possibilities to carry out a number of runs on Grid load at varying outputs.

The method adopted in this particular instance was to calibrate the closed ventilating air circuit of the alternator against a known loss artificially introduced into the air circuit and to obtain the loss by temperature measurements of the calibrated air for each individual test.

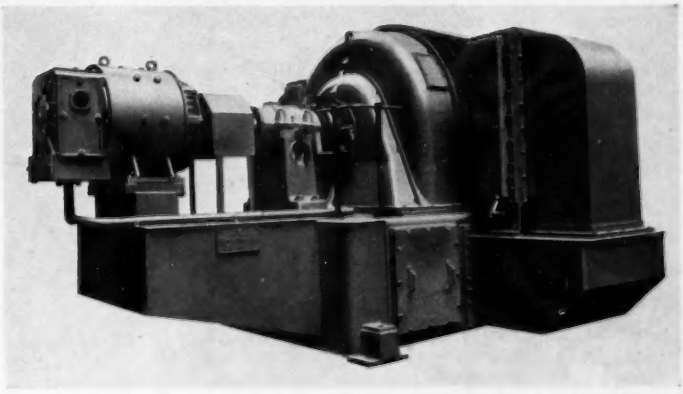


Fig. 3.—2,000 kW, 3 3 kV, 1,500 r.p.m. geared turbo-alternator for Raipur Central Province, India.

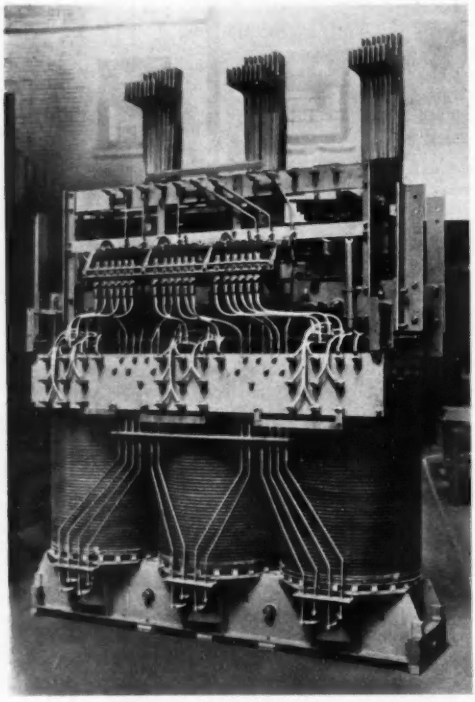


Fig. 4.—4,140 kVA furnace transformer 11 kV/399 volts, 7,300 amps. showing off-load tapping switch.

This method requires that air temperature measurements be made with the maximum degree of accuracy. To this end, banks of multiple thermocouples were specially arranged in the air on the hot and cold sides of the cooler. The loss measurements taken in this way were remarkably consistent and the loss curves followed very closely the anticipated figures.

The tests showed that the alternator complied in all respects with the guarantees of the order, and, furthermore, provided valuable data for the relative test values between light load and actual Grid load conditions of operation.

In view of the successful outcome of these tests, it is anticipated that further tests of this type will be made when suitable opportunity arises.

Transformers, Reactors and Condensers.

Orders continue to be received for transformers for a great variety of purposes and, in general, particulars of those for specific purposes such as for use with rectifiers, heating or lighting equipment will be found in the sections in which that apparatus is described. It may be appropriate, however, to record here that two 4,140 kVA furnace transformers, which are generally similar to those already supplied, have been ordered by Albright & Wilson (fig. 4). The input is 11 kV, 50 cycles, 3 phase ; the output voltage is regulated by means of tapping switches. An off-circuit switch is arranged to give 5 ratios and an on-load switch to provide a further 14 ratios on each of the off-circuit steps. Thus a total of 75 tapping combinations makes possible a vernier adjustment of output voltages between 100 and 230 phase to neutral. The off-circuit switch is electrically interlocked with the main oil switch.

Important contracts at present in hand for the B.E.A. include two 45,000 kVA transformers for the Midlands Grid System. The voltage ratio

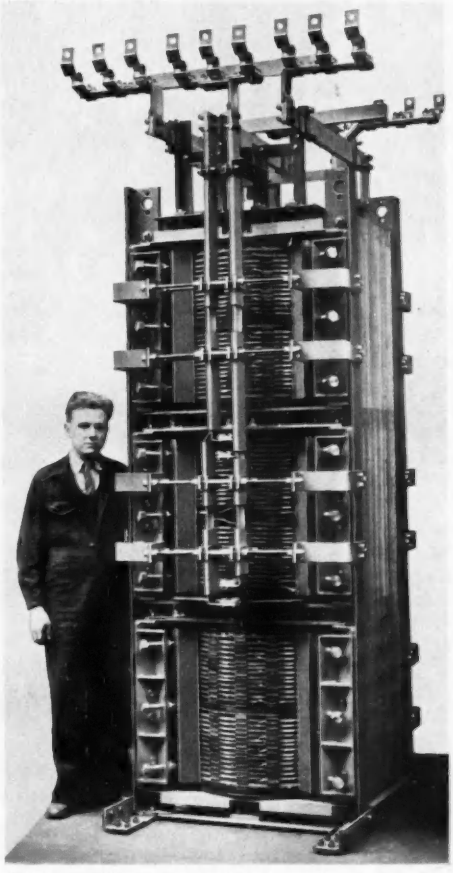


Fig. 5.—1,200 MVA, 6·6 kV, 3 phase, 50 cycle reactor for the British Electricity Authority.

is 132 kV/33 kV and tappings are provided on the high voltage side for a voltage variation of ± 10 per cent in 14 equal steps ; the on-load tap changing gear has local and remote control facilities. Two separate banks of radiators are fitted for cooling. Natural oil cooling is sufficient to enable the transformer to be operated continuously at half load ; at higher loads forced oil circulation with air blast cooling is employed, the fans being automatically brought into operation by the closing of electrical contacts within the winding temperature indicator.

For Welwyn Garden City a 10,000 kVA, 31,500/10,750 volt transformer is being built. It is star/star connected and has a delta connected tertiary winding designed to suppress any third harmonic components of induced E.M.F. An off-circuit tapping switch is arranged to give a secondary voltage variation of − 2½ per cent + 2½ per cent and + 5 per cent, while an on-load switch provides for plus and minus 10 per cent variation in primary voltage in ten equal steps. The transformer is designed for outdoor service and a separate bank of radiators mounted alongside ensures adequate cooling. Automatic control gear for the on-load tap changer is housed in a nearby cubicle.

Mention may also be made of a repeat order for three 3,000 kVA, 11 kV/6·6 kV transformers for Rotherham Corporation. An on-load tapping switch is fitted to each transformer to compensate for a primary voltage variation of 10 per cent in 10 steps of 1 per cent.

Two ironclad reactors have been made for the Mersey and North Wales area of the B.E.A. (fig. 5). They are of the three-phase magnetically shielded oil-cooled type rated at 1,200 kVA giving 6 per cent reactance on a 20,000 kVA, 6·6 kV system.

In the last review of progress in this Journal mention was made of a complete rolling mill equipment for Austral Bronze Co. (Pty), Ltd., Sydney. A 150 kVA, 3 phase, 5 kV, 50 cycle oil-cooled condenser is being manufactured for this undertaking, the equipment comprising a number of standard unit boxes suitably connected in series and parallel. The condenser is for use with a 1,100 h.p., 5 kV, 3 phase slipring induction motor in order to correct the power factor from 0·89 to 0·95 lagging. A protective current transformer device which controls external relays is also fitted in the same tank, the scheme being specially devised to ensure adequate protection of the condenser elements.

A 350 kVA, 3 phase, 6·6 kV, 50 cycle, oil-cooled condenser is in hand for Yarraville. Ninety-nine 12 spool boxes are used in its construction, suitably connected in series and

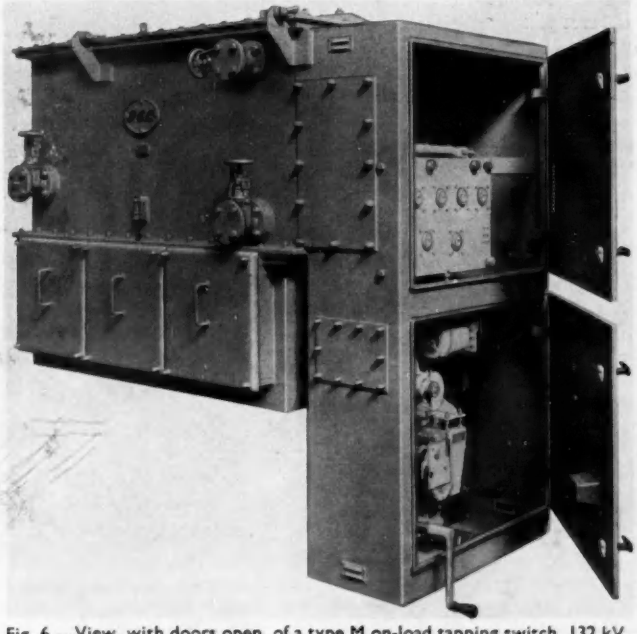


Fig. 6.—View, with doors open, of a type M on-load tapping switch, 132 kV, 250 amps.

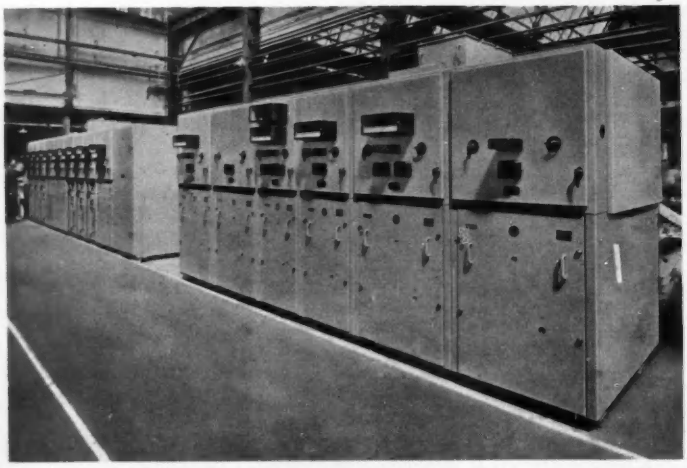


Fig. 7.—11 kV, 250 MVA double busbar metalclad switchgear ; a 16-unit board for a substation in Birmingham.

parallel. A protection scheme similar to that just described is incorporated here also.

Transformer Tapping Switches.

A description and illustration of the type J on-load tapping switch was given in an earlier issue of this Journal.[1] The success achieved by that switch has prompted a review of the situation below the economic limit of the type J switch, which is approximately 15,000 kVA. As a result, it was decided to design a switch to cover the range of 5,000 kVA to 15,000 kVA embodying Grid conditions, and to follow closely the design of the J switch as far as practicable. Obviously in producing such a design strict regard had to be paid to cost and such refinements as drop-down tanks had to be sacrificed.

Generally speaking, however, the same fundamental construction has been employed as for the type J switch, emphasis being laid on the compactness of design so that it can be readily fitted to transformers of 5,000 kVA. This type M switch (fig. 6), the rating of which is 250 amps. against the 500 amps. rating of the type J switch, has now been subjected to a searching life test of 30,000 operations. The intention is that the type M switch shall be in full production by the middle of the year.

[1] "Electrical Progress and Development," *G.E.C. Journal*, Vol. XIV, No. 3, February, 1947.

Metalclad Switchgear.

During the year a new range of metalclad switchgear has been introduced, the first orders completed being for two switchboards comprising a total of 34 units, for substations in Birmingham. The 16-unit board is seen in fig. 7. Orders for a larger number of equipments are in course of execution for other stations of the B.E.A. The new switchgear is rated at 250 and 350 MVA at 6·6 and 11 kV; busbars and circuit breakers are available in a wide range of current ratings up to and including 2,000 amps. The gear is of very good appearance; the front panels are flush with the fronts of the pedestals, and the busbar and current

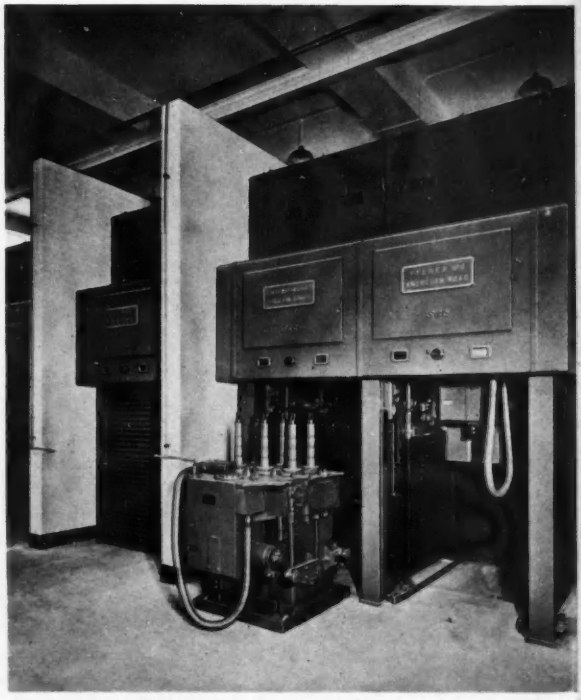


Fig. 8.—33 kV, 750 MVA double busbar heavy duty metalclad switchgear in a substation at Coventry. One shutter is seen raised and one circuit breaker withdrawn.

transformer chambers are enclosed by neat steel covers.

The new range differs from the 250 and 350 MVA "subgear" principally in that the gear has been considerably reduced in height by mounting the breaker and its hoist gear on a horizontally withdrawable carriage. The breaker is isolated from the busbars and cable connections by lowering it by means of the worm gear operated hoist. Once the breaker is lowered the carriage may be withdrawn from the unit; after the tank bolts have been removed the hoist gear may be used to raise the breaker top plate with the contacts free of the tank, for inspection and maintenance.

The switchgear is available both for single and duplicate busbar schemes; in the latter case the changeover is effected by the off-load transfer breaker method.

The oil circuit breaker is of the double break type with side blast arc control pots and is generally similar in construction to the existing range of breakers of 500 MVA capacity and above.

When a feeder voltage transformer is required it is conveniently mounted on the top of the unit over the current transformer chamber and is of the horizontally withdrawable type. The arrangement is such as to give ready access to the current transformers when the voltage transformer has been withdrawn. If necessary the units may be arranged for mounting against a wall, the cable boxes being accessible from the front of the switchgear.

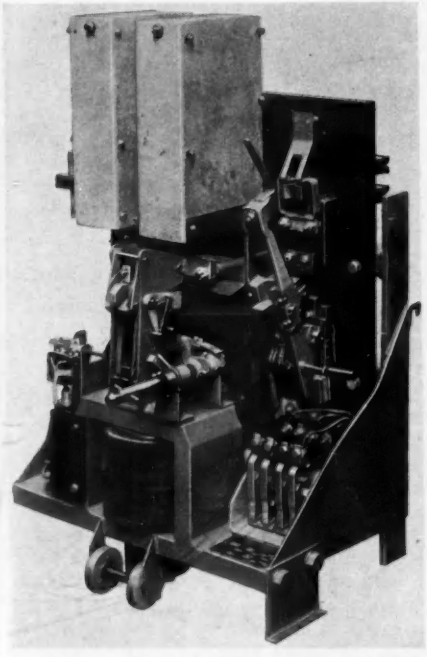


Fig. 9.—Front view of Solenoid-operated air circuit breaker for a 400 volt, 25 MVA, eight-panel board for Palestine Electric Corporation.

Heavy Duty Metalclad Switchgear.

Numerous installations of heavy duty metalclad switchgear have been completed both at home and overseas and a large amount of this type of equipment is in course of construction for the British Electricity Authority, British Railways and for export. A 33 kV, 750 MVA double busbar board installed in a substation in Coventry is seen in fig. 8. One shutter is shown raised and one circuit breaker withdrawn. An order of especial interest concerns the 84 units being built to the order of the International Construction Company of Johannesburg for the Vanderbijl Park Works of the South African Iron and Steel Industrial Corporation.

Airbreak Circuit Breakers.

Considerable progress has been made with the production of medium voltage airbreak circuit breakers for 15 and 25 MVA at 400 volts.

The circuit breakers are completely enclosed in cubicles of pleasing appearance and of bent sheet steel construction. Space is allowed within the enclosure for internal isolation of the breaker from the busbar and cable connections. The breakers are arranged for hand or solenoid operation and in the latter case the control switch may be mounted on the unit or on a panel remote from the switchgear (fig. 9).

Space is available for mounting a reasonable number of flush type instruments on the cubicle doors and the arrangement of the switchgear is such that further instruments may be conveniently mounted when required.

In conjunction with similar cubicles housing H.R.C. switch fuses and latch-in contactors, these airbreak circuit breakers are particularly suitable for the control and protection of power station auxiliaries.

Outdoor Oil Circuit Breakers.

A new operating mechanism housing has been developed, forty-five of which are now in process of manufacture, for use with the 33 and 66 kV low oil content circuit breakers. Castings have been completely eliminated and the housing is entirely fabricated from bent steel plate.

Three doors, one at each side, and a main front door allow maximum accessibility to the internal parts; the circuit breaker mechanism is

in the upper portion of the enclosure, while the control switches and push buttons, solenoid contactor, fuses and auxiliary wiring terminals are conveniently mounted in the lower half.

Provision is made for bringing in any required number of multicore cables. An interesting constructional feature of the new design is that the whole of the mechanism may be completely assembled on the main frame before the enclosure, which carries the doors, is added.

Control Boards.

Control panels for power station and general industrial service are now built of steel plates with the edges bent to form flanges by means of which they can be bolted together to form a cubicle construction. In this way the use of angle iron and other rolled sections becomes unnecessary and the result is a light, rigid structure of pleasing appearance. Each cubicle is designed on the unit principle so that extensions are very easily made to form a multi-

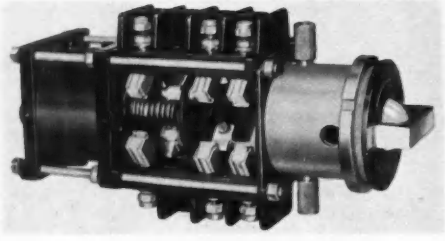


Fig. 10.—Semaphore switch for remote control boards.

panel control board. The flanges formed by the double bends are pierced at standard intervals with holes for mounting internal apparatus such as cable gland supports, wiring cleats, and so forth. Doors are provided with internal hinges so designed as to ensure close fitting, thus presenting a continuous unbroken surface on a long control board.

A comprehensive range of components for remote control boards has now been standardised and includes such items as key synchronising switches, combined circuit breaker control switches and semaphores, semaphore indicators, motor control switches, field regulator switches, ammeter switches and the like. The designs have the advantage of giving uniformity of appearance combined with simplicity of fitting. In every case only one hole has to be drilled in the panel, each component then being secured in place by a clamping ring. Figs. 10 and 11 show respectively a combined semaphore and control switch and an alarm relay.

Protective Gear and Relays.

Great progress has been made in the design and production of protective relays and in their application to the protection of all kinds of electrical apparatus, cables and transmission lines. The technical co-ordination of all this work is carried out by Witton Works, which also manufacture certain of the relays. Other relays, in particular those of the induction type, are made by the Chamberlain and Hookham Meter Works while still others are made by Salford Electrical Instruments Ltd. In this way the technical and manufacturing experience of the three organisations is brought together and used to the best possible advantage.

In the following paragraphs some of the more notable recent developments are described.

Load Bias Busbar Protection.

Several schemes of busbar protection have

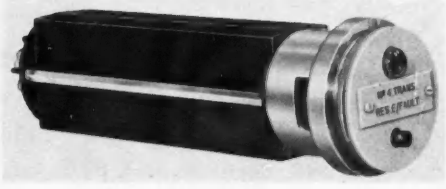


Fig. 11.—Alarm relay for remote control boards.

been developed to meet the demand for the complete protection of the busbars of power stations and major substations.

All these schemes embody the load bias principle, according to which the protection operates by balancing the summation of all the currents flowing into the busbars against the summation of all the currents flowing away from the bars, the balance being biased in the non-operating direction by the arithmetic summation of all the currents.

The principle is, in fact, derived from the well-known McColl biasing schemes which have been used by the G.E.C. for very many years.

Very elaborate and careful tests which have been made in the Works, in the High Power Testing Laboratory and on site have shown that these schemes possess those qualities which are essential to a modern protective system, namely:

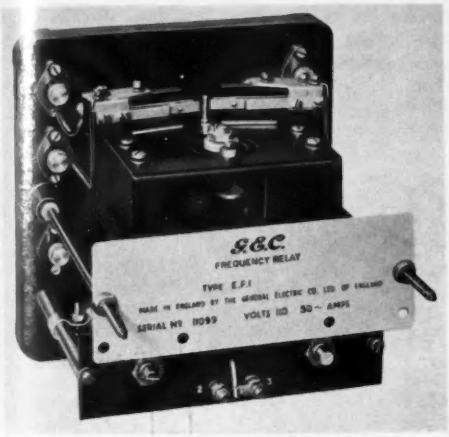


Fig. 12.—Frequency relay, type E.F.1, with cover removed.

(*a*) high sensitivity of setting,
(*b*) high speed of operation,
(*c*) complete stability under all conditions of load and through-faults,
(*d*) complete reliability and great robustness in all the components.

The schemes have already been applied to a number of very large installations and the table below shows some of the results which have been obtained.

Schemes are available both for earth fault protection only and for combined earth and phase-to-phase fault protection.

relays may be controlled from the panel which houses the busbar protective equipment.

RELAYS.

Among the new relays which have recently been produced the following may be mentioned:

(*a*) **High-speed Moving Iron Relays.**

These are an entirely new development which is the result of several years' work. By the use

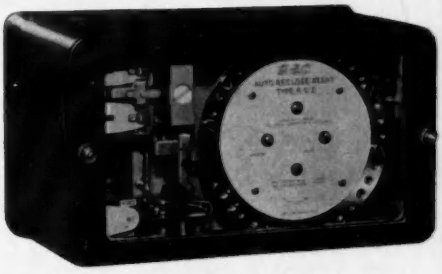


Fig. 13.—Auto-reclose relay, type R.G.2.

of a new principle of construction it is possible to obtain very high speed of operation and high operating torque with a very small consumption of power. The relays may be arranged to be responsive to current, voltage, wattful and wattless power components, frequency, power factor, etc. As an example fig. 12 shows a frequency relay, type E.F.1. Both the mean frequency and the sensitivity are independently adjustable, the

A System voltage kV	B MVA rating of switchgear	C Maximum through-fault current (amps.)	D Maximum available earth fault current (amps.)	E required earth fault setting (amps.)	F Speed of operation at three times E	Stability ratio C/E
33	1,500	26,300	1,200	240	0·03 secs.	110
11	1,000	52,600	2,000	400	0·03 secs.	132
11	1,000	52,600	3,000	600	0·03 secs.	84
132	2,500	11,000	Solid earthing of neutral	500	0·03 secs.	22

A busbar protective equipment by its nature is called upon to act only very infrequently. The importance of regular testing and maintenance is thus very great. In order to make this easy it is usual to provide secondary injection testing gear as an integral part of the equipment; this is generally so arranged that the testing of all the current transformers and

latter down to a figure of $\pm 0{\cdot}4$ per cent of the mean frequency. Thus a relay having a mean frequency of 50 cycles per second will make contact in one direction if the frequency rises to 50·2 cycles per second or in the other direction if the frequency drops to 49·8 cycles per second. The power consumption of the relay is 2 VA.

(*b*) **Graded Time Reclosing Relay.**

This relay, known as type R.G.2, is shown in fig. 13. It was designed to control the automatic reclosing of circuit breakers in traction substations, but is suitable for any similar service.

Arrangement No.	On energising the relay	On de-energising the relay
1	Contact makes after time delay	Contact breaks instantly
2	Contact breaks after time delay	Contact makes instantly
3	Contact breaks instantly	Contact makes after time delay
4	Contact makes instantly	Contact breaks after time delay

The relay will carry out the following operations :

(1) Any desired number of reclosures within a maximum period of 120 seconds with intervals of 5 seconds upwards.
(2) After completion of the prescribed reclosing cycle without a satisfactory reclosure, the relay will lock out.
(3) If a satisfactory reclosure is made, the relay resets instantaneously.

The relay contacts and operating mechanism are extremely robust and are suitable for direct connection to A.C. or D.C. supplies at any voltage up to 600 volts. An anti-pumping device is included so that the circuit breaker can reclose only once at each reclose position of the relay. Facilities for remotely locking out and resetting the relay may be provided.

(*c*) **Instantaneous Relay.**

This relay, known as type AOC, is of the instantaneous attracted armature type ; it is extremely sensitive and quick in action. The standard coil ratings are 5 amps., 1 amp. and 0·5 amps. and the standard ranges of setting are 10-40 per cent, 20-80 per cent, 50-200 per cent and 100-400 per cent of the current rating. The relay is thus suitable for earth fault protection, overcurrent protection and for general use where a highly sensitive instantaneous relay is required.

It operates in 0·02 to 0·03 seconds at a current equal to three times the setting and is supplied with two normally open contacts capable of making a load of 750 VA. A clearly visible flag indicates when the relay has operated.

(*d*) **Time Delay Relay.**

This relay, known as type TDR, is a robust apparatus suitable for general application to automatic substations and similar work. The movement comprises a solenoid and a clockwork escapement and can be supplied for a number of different time ranges covering periods of 0 to 210 seconds. The relay is fitted with two contacts which can have various functions as tabulated above.

The relay is suitable for systems up to 600 volts A.C. or D.C. and the contacts are capable of making a circuit of 2,000 VA or breaking a circuit of 500 VA.

Mercury Arc Rectifiers.

Large numbers of rectifier equipments have been manufactured for a variety of applications both for home and overseas use. In addition, detailed improvements and innovations in this field have continued. Typical of these is the introduction of rectifiers with additional anodes for supplying the fields of D.C. motors. This enables a single grid-controlled rectifier to operate as a complete unit for a variable speed D.C. drive, the motor armature being supplied with a smoothly adjustable D.C. voltage from the main grid-controlled anodes, and the motor field from the " field anodes ". By this means the reliability attainable with the main supply is also available for the field ; units of this kind are particularly valuable for rolling mill drives, and so forth, for which they are now being supplied.

Another innovation, again directed towards greater reliability, is the introduction of a small steel tank pumpless rectifier for key operations under arduous conditions where the robustness of steel is needed. It may be mentioned that one of these small rectifiers has been operating daily for about twelve months in the rectifier-inverter drive referred to in the article on page 52.

Improvements continue to be made in the methods of grid control including the electronic control of static phase shift networks giving voltage control over the whole of the rectifier voltage range. Another interesting device, in the form of a ball bearing type slipping clutch,

has been introduced into the mechanically driven phase shifting transformers used in the older forms of grid control to eliminate the risk of overrunning limit switches or shearing driving gears.

A number of pumpless air-cooled steel tank rectifiers, which will ultimately form part of Rotterdam, several units of various capacities for India, and two 1,000 kW transportable grid-controlled equipments for Argentina.

Of the many rectifier equipments built for the home market one of the most interesting is the 1,050 kW equipment for a rolling mill drive for the Lancashire Steel Corporation, Ltd.

Fig. 14.—A consignment of mercury arc rectifiers for various overseas territories, in course of construction.

complete equipments for export to all parts of the world, is seen in fig. 14 in course of construction in the assembly bay of the Mercury Arc Rectifier Works.

During the first part of the year just passed, rectifier equipments were supplied to India, Australia, Argentina and China, in addition to those built for home use. The many diverse applications include traction, industrial, mining, chemical works service and electrical supplies for research stations.

Amongst the rectifiers for export, either recently supplied or under construction, are three 1,000 kW, 600 volt traction units for Brisbane; eight 1,500 kW, 1,600 volt units for main line traction, and eleven units for the New Zealand Government Railways and one 1,500 kW, 1,500 volt unit for the New South Wales Government Railways. Wellington City Council has also ordered nine equipments aggregating 5,400 kW for both 2-wire and 3-wire operation with static balancing. There are three 600 kW units for Johannesburg, three 1,200 kW units for which incorporates field anodes in the rectifier cylinder. Similar orders are in hand for India.

CABLES.

A number of new developments have taken place in the manufacture of power cables which have the effect of increasing durability, improving service efficiency and, in special cases, also of giving greater assurance of safety under particularly arduous conditions. Details are given later of the outstanding record of reliability of a cable that had been in service for more than sixteen years and had been subjected to the full rigour of the air-raids on London.

Tellurium-Lead Sheathing.

Paper insulated cables which will be exposed to abnormal mechanical stresses in service or in transit are now, unless otherwise specified, sheathed with an alloy consisting of 99·985 per cent lead and 0·015 per cent tellurium, applied to the cable by continuous extrusion. The fatigue resistance of this very dilute alloy is

practically as high as that of Alloy E, British Standard No. 801, in which the total percentage of alloying materials, tin and antimony, is about forty times as great.

As extruded, the tellurium alloy is almost as pliable as pure lead but is more resistant to mechanical damage on account of its property of toughening under deformation or impact.

Non-ignitable Filling Compound for Cable Joints.

A compound has been developed which cannot be ignited by a power arc when ejected in the molten state from a cable joint or terminal that has failed. The development work was undertaken at the request of H.M. Chief Electrical Inspector of Mines, and the compound produced has received the approval of his Department. It has excellent dielectric properties and is suitable for use in any electrical equipment where bituminous filling compound would normally be employed.

Rot-proofed Textile Wrappings for Underground Cables.

To reduce to a minimum bacterial decomposition of the protective textile wrappings, such as cotton cloth and jute hessian, which are used with underground cables, an improved preservative is now incorporated in the bituminous waterproofing medium with which the fabrics, etc. are impregnated before application to the cable. Apart from the longer life of the protective wrappings and hence of the other external components of a buried cable, there is also the certainty that cable stored on the drum for long periods under unfavourable conditions would be found in first-class condition when eventually required for use. A more concentrated application of the preservative can be made as a protection against termites.

Stainless Steel Sheathed Cables.

Cables sheathed by forming a stainless steel strip into a tube round the insulated conductors and closing the seam by welding are sufficiently strong to withstand suspension in the length of a normal span without any additional means of support.

Cables so sheathed are resistant to corrosion by atmospheres containing sulphur-acids which rapidly destroy galvanised coatings ; hence they provide an excellent solution of the problems associated with overhead suspension cable in highly industrialised areas. In spite of the great strength of the sheathing material the cable is reasonably flexible, presenting no serious difficulties in installation or jointing.

Continuous Lead Extrusion Machine.

The Pirelli-General patented continuous lead extrusion machine is still gratifyingly popular with cable makers throughout the world. Machines have recently been sold to the United States and Canada and further orders have been received from no fewer than seven different countries.

The machine itself is continually being improved, a recent modification being the introduction of a Michell type bearing to take the main thrust. This has eliminated difficulties caused by ball thrust breakdowns, while the special lead loaded oil used for lubricating the bearing is beneficial to the gearing. A sight feed indicator has been added to the lubrication system. A reduction in the number of splines in both stationary members has resulted in lower motor loads and facilitated the extrusion of alloys.

Long Service Tests on 132 kV Cables.

Recently the opportunity occurred of reclaiming a length of single-core 132 kV oil-filled cable after 16 years' continuous service. Laid in 1930, this cable was included in one of the original 132 kV installations and during the air-raids on London was subjected to many severe surges. Post-war reorganisation of the London power transmission system involved a route deviation which rendered some of the cable redundant and thus available for testing. The results of these tests demonstrated the extraordinarily high electrical stability which may be expected from oil-filled cable in service.

For the test, three lengths : two of 110 yards and one of 220 yards were used and the original high voltage acceptance test applied. Subsequently the original routine power factor/voltage test was carried out on each test piece. In the former test each length withstood 176 kV, 50 cycles for 15 minutes between conductor and sheath. In the latter test each length was subjected to 50 per cent, 100 per cent and 150 per cent of normal voltage, the following being the comparison of average values obtained :

Percentage normal voltage	50	100	150
1930	·00245	·0025	·0027
1946	·0024	·0025	·0027

A short length of cable was then subjected to some special high voltage tests as below :

(1) The original C.E.B. acceptance type test of 304 kV, 50 cycles (equivalent to 525 kV, 3 phase) applied for 15 minutes between conductor and sheath.

(2) 250 kV, 50 cycles (equivalent to 430 kV, 3 phase) applied for 50 hours between

conductor and sheath without failure or appreciable change in power factor.

( ) A piece of cable between sealing ends was subjected to twelve 50 cycle dry flashover test . These reached an average of 360 kV (equivalent to 623 kV, 3 phase) without failure of the cable.

Careful examination of insulation from widely separated points revealed no evidence of deterioration either in the paper or the oil. The viscosity of the oil remained unchanged.

Mention has been made of the abnormally severe conditions imposed by the London air-raids and it will be of interest to record one or two examples of what actually occurred to the oil-filled cables.

On one occasion a straight-through joint was hit by an unexploded bomb which reduced the overall diameter of a part of the case from about 11 ins. to 3 ins. The joint continued to operate for many days before it was found convenient to carry out repairs.

A 2,000 lb. bomb fell directly on the route of a double circuit 132 kV Central Electricity Board feeder laid under the roadway at a depth of approximately 3 ft. 6 ins. On inspecting the bomb crater, which was some 15 to 18 ft. deep and occupied the full width of the road, no trace of the cables could be seen. They were eventually found to have been forced down and buried in the bottom of the crater.

The impact had actually increased the length of the cable, stretching the lead sheaths but without causing any loss of oil. The cables were still carrying their normal load.

The cables in question were six single-core, 132 kV oil filled, which continued to operate satisfactorily for a considerable time and were ultimately replaced without having failed electrically in any way.

As an example of the speed with which repairs can be effected it is worth mentioning that cables which had been completely severed and the oil drained out of them were reconditioned, re-jointed and put in service again within three days.

In another incident a cable joint was struck by an A.A. shell which exploded on impact with the concrete joint container. Service was maintained for some hours and although there was considerable loss of oil from the damaged joint sleeve which was flattened and torn, no electrical failure occurred.

Overhead Lines.

The department dealing with overhead lines has recently been expanded by the formation of a design section which will specialise on such structures as lattice steel towers, reinforced concrete poles for transmission lines as well as radio towers.

Important contracts in hand include the towers for the London-Birmingham television link and the radio communication system for the Middle East pipeline for both of which fabricated galvanised steel lattice towers are employed varying in height from 60 ft. to 350 ft.

MINING GEAR.

Winding Engine Equipment.

In connection with the modernisation of the mines, several winding engine equipments in course of construction at Erith Works are worthy of note.

A geared D.C. twin-motor drive Koepe pulley winder is being built for Bradford Colliery. The wheel diameter of the pulley is 24 ft. and it is of interest that the complete winder is to be erected in a reinforced concrete tower arranged directly over the shaft, the winder floor level being approximately 200 ft. above the shaft collar. The duty cycle allows for winding a useful load of twelve tons from a depth of 3,850 ft. in 92 seconds which, with an extra 16 seconds for decking, is equivalent to an output of 400 tons an hour.

Another interesting equipment is that at present being erected at Calverton Colliery, near Nottingham, which is one of the few double-drum winders to be installed in this country. There is one fast drum and one loose clutched drum, each being 17 ft. 6 ins. diameter and 7 ft. wide between flanges. The drive is from a 1,750 h.p. reversing slipring motor through single reduction gears. This hoist is designed to wind a useful load of 10 tons from a depth of 1,680 ft. at a maximum rope speed of 1,580 ft. a minute giving an output of 400 tons an hour.

As the equipment will be used for shaft sinking it will be installed as a single-drum hoist, the loose drum being fitted when the final depth is reached. However, before this is attained the shaft will have to pass through a layer of sandstone at about the 400 ft. level, which acts as the watershed for the Nottingham area, and it is expected that water at the rate of about 1,000 gallons a minute will have to be contended with. To surmount this difficulty the engineers of the National Coal Board are arranging to freeze the shaft at this level and it will be kept frozen, thus holding back the water, until the shaft lining has descended well below the danger level and there is no further possibility of trouble from this cause.

A third equipment which is being supplied incorporates a number of unusual and interesting

features. This is the first of two hoists for the Welsh Navigation Collieries and will be required to hoist from two levels simultaneously. Very careful consideration was given to the problem and it was decided that in order to achieve the most economical operating cycle the drum should be of unorthodox construction. It is therefore being made with the cylindro-conical portion 12 ft. to 18 ft. 6 ins. diameter by 3 ft. 3 ins. wide for coiling the longer rope, the other half being of parallel construction, 12 ft. diameter by 5 ft. wide.

Yet another new feature incorporated in this equipment concerns the brake engine. Hitherto it has been general practice to apply the brake through the medium of a falling weight. However, G.E.C. engineers have felt for some considerable time that with modern equipment calling for short winding cycles, this type of brake was no longer suitable on account of its comparatively slow action. Accordingly, a power-operated brake engine has now been developed in which the brakes are applied by oil pressure, the weight being retained as a safety precaution and coming into operation only in the event of an electrical trip-out or in an emergency. The behaviour of this engine in service is to be carefully studied and it is hoped to be able to publish some useful data in due course.

It should be added that this hoist is driven through single reduction double helical gearing by a 1,300 h.p. slipring induction motor and is designed to raise 2·4 tons of coal or 4 tons of stone from 1,596/1,131 ft. on alternative winds at 3,000 ft. per minute and 1,960 ft. per minute respectively.

Dynamic Braking of A.C. Winders.

There has been considerable development in connection with the dynamic braking of A.C. winders by the method of exciting the motor stator with direct current. Means have been devised to counteract certain inherent defects from which this system suffered hitherto. These were : instability, in that under certain conditions increasing speed does not correspond to increasing torque ; undue heating of the rotor windings at low speeds on account of reduced ventilation.

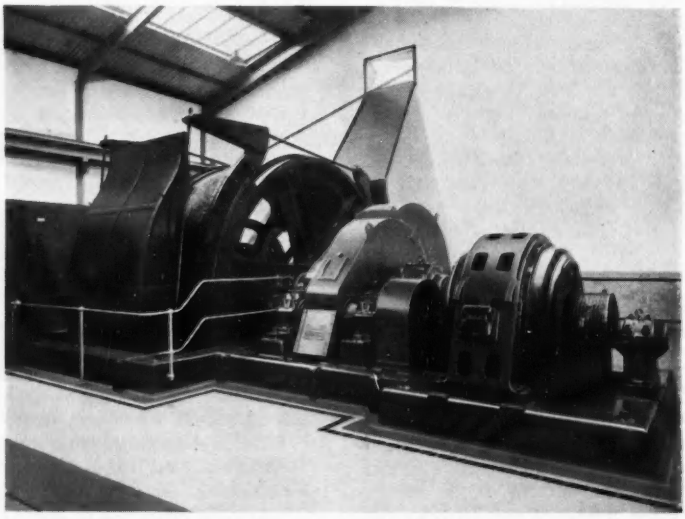


Fig. 15.—A geared A.C. winder equipment at the Babbington Pit, East Midlands. The slipring motor is rated at 925 h.p., 3·3 kV, 490 r.p.m.

It is now possible to ensure that the value of resistance in the rotor circuit is that best suited to the load and speed thus ensuring the minimum of heating with the most efficient and stable braking. The action is automatic in that it is self-adjusting to meet the required conditions. The elimination of excessive losses obviates overheating and the braking torque, which is adjustable over a wide range by the driver's hand lever, is automatically maintained.

Stator Reversing Gear.

The importance of electrical equipment for mine hoists has led to improvements in the design

of individual components. Stator reversing contactors for use with geared A.C. winders, suitable for 3·3 kV and for currents up to 600 amps., have recently been fitted with a new type of arc chute designed to increase braking capacity, decrease the rate of wear and to afford easier access to the contacts. The better performance has been achieved by providing a very powerful shunted blow-out coil, more numerous arc splitters within the chute and by improving the operating characteristics of the closing magnet. A view of the reverser with the arc chutes raised is seen in fig. 16.

Flameproof Motors.

The re-equipment of British mines is a long term policy which involves the manufacture of a great variety of electrical equipment, most of it of special design to suit the particular conditions in which it will be required to operate. As has been noted in previous reviews, there has been an increased demand for flameproof motors and in consequence the range of these is being continually extended. In recent months orders have been received for large flameproof A.C. motors of 100 h.p. and 150 h.p. rating at 3·3 kV and for 260 h.p. and 500 h.p. at 6·6 kV ; these machines involve frame sizes larger than those so far covered by Buxton certificates. In preparing the necessary designs for these motors, which are of the totally enclosed fan cooled type similar to smaller motors already built, advantage has been taken of the opportunity to arrange that other outputs shall be obtainable from the particular frames used. In due course Buxton certified flameproof motors will be available for a wide range of outputs and speeds.

ROLLING MILLS.

Steelworks.

Additional orders have been received from the Steel Company of Wales for a considerable quantity of electrical equipment for the new Abbey Works. The generating capacity is being increased by the installation of a 2,200 kVA geared turbo-alternator set ; sixteen 400 kVA transformers with off-load tap-changing gear are being supplied for local distribution inside the Works. A further 300 industrial type A.C. motors, totalling 5,000 h.p., are on order for auxiliary drives for blast furnaces, coke ovens, conveyors and the like.

Motors are also being supplied to drive the auxiliaries on a 45 in. slabbing mill which rolls slabs up to 60 ins. wide by 8½ ins. thick from ingots weighing up to 20 tons. The ingot

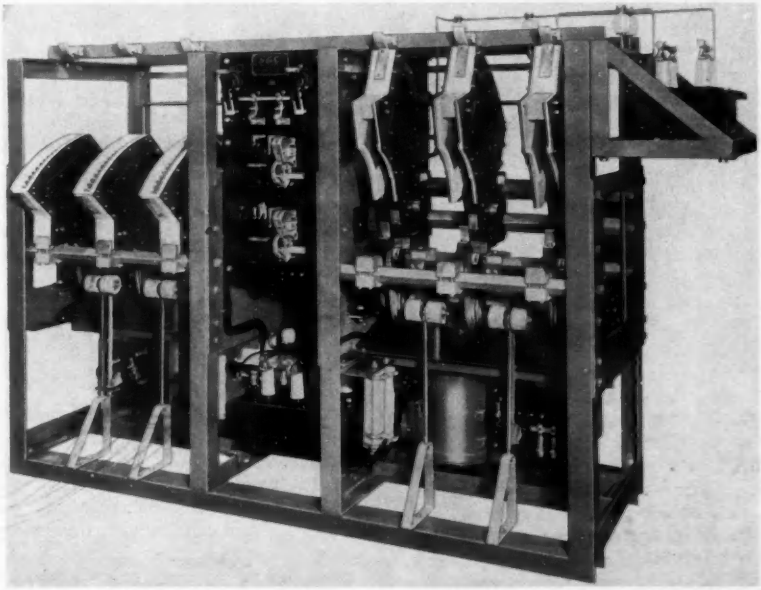


Fig. 16.—3·3 kV solenoid-operated stator reverser for the Calverton Colliery of the National Coal Board. The arc chutes of one set of contactors are seen raised.

buggy, mill tables, screwdowns, manipulators and the slab shear are driven by an aggregate of 20 D.C. motors totalling over 3,700 h.p. Two 2,000 h.p., 8-machine motor generator sets supply the necessary power for these machines.

Further motors for the auxiliary drives of an 80 in. hot strip finishing mill comprise 296-1·6/4·3 h.p. shunt wound motors for driving the rolls on the runout tables, two 430 h.p., mill type motors for the flying shear and two 300 h.p. and two 75 h.p. motors for the coiler drives. D.C. power for these auxiliaries is provided by two 1,550 h.p. motor generator sets.

Much equipment is also on order for Trostre and includes the complete drives for two 2-stand temper mills in the cold reduction plant. The main drive is by 1,000 h.p. D.C. motors while an aggregate of 4,000 h.p. is required for the reelers, uncoilers and roll drives. The motor generator sets supplying the necessary power are driven by 11 kV salient pole synchronous motors. Equipment for the pickling line comprises 13 D.C. motors aggregating 1,500 h.p. and a 1,250 h.p., 11 kV motor generator set.

INDUSTRIAL ELECTRIFICATION

The "Mutac" Switch.

An account of the progress achieved with the "Mutac" switch and of the methods adopted for quantity production and automatic testing was given in an earlier review in this Journal.[1] In the meantime the range of these switches has been extended by the addition of two more types: a 5 amp. ceiling switch and a 10 amp. switch for fixing to American type boxes.

The noteworthy features of the new ceiling switch, which is made in single and two-way models in brown and cream, are the silent operation common to the Mutac series, easy replacement of the operating cord and ability to function in any position. The switch is of the micro-gap type and is basically the same as others of this design, with the addition of a cord-operated mechanism. The moulding in which the electrical contacts are mounted and the dolly have been specially designed for this switch. The cord-actuated operating mechanism is housed in another moulding, constituting a sub-assembly which is secured to the switch body by riveting. A steel link, one end of which meshes in a slot in the dolly, transmits the impulse from the cord to the dolly. The special contour of this slot together with a spring return gives the type of reciprocating operation essential for a ceiling switch.

The interior of the switch and the cover are shown separately in fig. 17. When assembled the complete switch has a very pleasing and effective appearance and results show that these switches pass the British Standard tests by a handsome margin.

In certain overseas markets a demand was encountered for 10 amp. switches suitable for mounting in American type wall boxes.

A "Mutac" switch with basic features similar to those of the original series but provided with a metal strap and screws suitable for fixing to standard American type wall boxes is now available. A moulded switch plate in either brown or cream is also supplied, together with fixing screws. The screw heads are covered with Bakelite to match the switch plate.

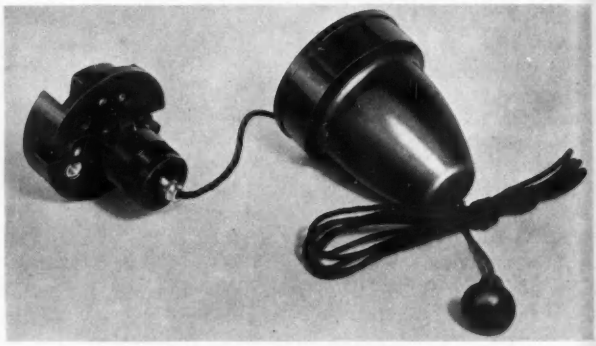


Fig. 17.—"Mutac" ceiling switch with cover removed.

Textile Mill Electrification.

The variable speed system of spinning cotton yarn has many advantages; for this purpose variable speed A.C. motors with automatic regulators have been especially developed (figs. 18 and 19).

It is notable that this type of equipment has been installed in the Poli-Khumri Mill in Afghanistan which the G.E.C. has electrified throughout. Briefly to explain the method of operation, it may be said that with constant speed ring spinning frames it is impossible to maintain constant tension on the yarn which is thus liable to contain faults. Also, to avoid an excessive number of broken ends, it is necessary to limit spindle speed to the worst conditions which are met with when forming the base and

[1] "Electrical Progress and Development," *G.E.C. Journal*, Vol. XIV, No. 3, February, 1947.

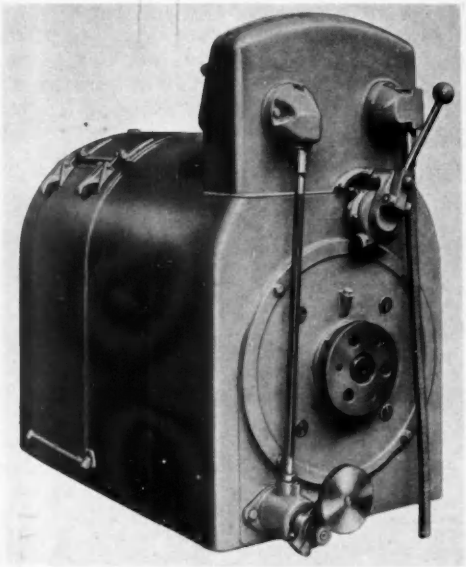
the nose of the cop. With variable speed spinning, however, a uniform yarn tension can be maintained resulting in an even yarn, firm package and increased production with a minimum of broken ends.

In the Poli-Khumri Mill each of the 35 ring frames is directly coupled through the tin roller shaft to a 6/12 h.p., 600/1,200 r.p.m. duct ventilated ring frame motor. There are two drives from the ring frame to the automatic spinning regulator: (1) a flexible shaft drive from the ring frame ratchet wheel mechanism operating the basic cam which in turn varies the motor speed throughout the whole build-up of the cop. This basic speed is slowest when beginning to build up the base of the cop and increases to a predetermined maximum when the full cop diameter has been reached, and is again reduced when the nose is being formed and the cop nearing completion. (2) The second drive is by a spur and pinion from the heart shaft in the spinning frame which operates the cyclic cam in the regulator. The cyclic cam varies the speed of the motor during every cycle of the ring rail, the speed being greatest when winding on to the full diameter and lowest when winding on to the bare spindle or tube.

At the beginning of the set when the cop base is being formed, little if any cyclic variation is permissible. In order to control the point at which the cyclic cam begins to function an adjustable hold-off stop is provided as part of the regulator. This controls the amount of cyclic speed variation at the beginning of the set, but permits full cyclic variation once the base of the cop has been formed.

With the automatic regulator a motor speed variation up to 300 r.p.m. is readily obtained on both the basic and cyclic cams by a simple adjustment of levers along calibrated scales. The spinning frame motor is started by means of an adjustable starting handle arranged on the motor at the spinning frame end and so designed that the motor can be started only at the lowest speed. The same handle is used to engage the automatic spinning regulator and a worm adjustment is provided which enables the operator to adjust the speed at which this comes into operation.

There is a big demand for these motors in the export market and more than 500 are in course of construction for mills in Argentina, Greece, Hyderabad, Egypt and South Africa.



Figs. 18 and 19.—Automatic ring spinning frame commutator motor, 6/12 h.p., 600/1,200 r.p.m. as seen respectively from the driving end (left) and from the commutator end.

Annunciator Units.

With the increasing use of electrical equipment in the textile industry, emergency trip systems have been applied to stop the machinery and indicate the location of a fault. In the operation of warping a large number of individual threads are wound on a single drum from a creeling

stand. Should a thread break, the warping motor must be rapidly stopped and an indication of the position of the broken thread given to the operator.

The threads are divided into separate banks each of which is connected to the annunciator

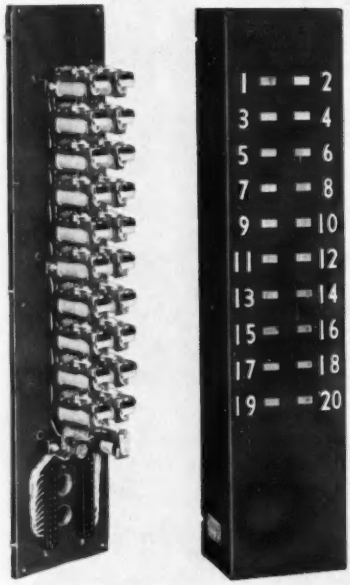


Fig. 20.—Annunciator unit for indication of warp breakage in a creeling stand.

unit shown in fig. 20. Breakage of a thread operates the appropriate indicator and simultaneously switches off the warping motor. Normally, this would result in the remaining indicators tripping due to all the threads on the creeling stand losing tension. To avoid this, there is a lock-out relay so that when the first indicator has tripped no further tripping can occur until the complete unit has been reset. Normally, resetting is performed automatically by interconnection with the starting button of the warping motor.

Type L.H. Relay for use with Lifts.

A new type of relay has been developed primarily for use on lift control circuits. The design is based on the low voltage telephone relay for operation on either A.C. or D.C. from 50 to 250 volts (fig. 21). Unlike telephone equipment which normally functions in air-conditioned surroundings, this relay is capable of operating satisfactorily under considerable variations in temperature and humidity as well as in dusty atmospheres. It is therefore much more robustly built than its telephone prototype and is eminently suitable for many industrial applications. The fact that it is capable of functioning for long periods without attention and requires no special skill to maintain it in good order has led to its being widely used with automatic control gear.

TRANSPORTATION.

As had been anticipated, there has been a great revival of interest in electric traction, both at home and overseas, and considerable development work is being actively pursued on traction motors, control gear and auxiliary equipment for both diesel-electric and straight electric rolling stock.

Trolley Buses.

Much equipment of post-war design is now in service on the road. In all cases compound wound motors are used with rheostatic electric braking.

Seventy-five equipments on B.U.T. (British United Traction) chassis for Cardiff Corporation are being delivered as rapidly as Government allocations permit. The ninety-four equipments for Belfast Corporation have been completed;

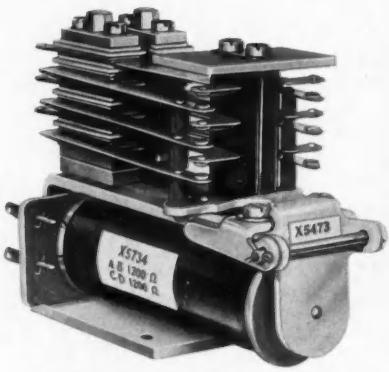


Fig. 21.—Type L.H. relay for use with automatic control circuits.

they comprise seventy non-regenerative type on Guy chassis and twenty-four of the regenerative type on B.U.T. chassis.

Progress has continued on the execution of the orders for Launceston and Hobart, Tasmania. The prototype chassis with its complete electrical equipment has been exhaustively tested and has given complete satisfaction in every respect. The chassis used is the B.U.T.

export type with rear-mounted control equipment (fig. 22) ; the motor is of the non-regenerative type, compound wound, designed for use with rheostatic braking.

Tests have been carried out on a tappet type master controller which was developed immediately after the war and of which some details have already been given[1] (fig. 23). It is confidently anticipated that it will be possible to seal up all the working parts, including the contacts, and leave them untouched for well over a year. In all probability they will be attended to only when heavy overhauls are made.

An entirely new form of electric braking has been developed for trolley buses. It has been very fully tested and will shortly be put into service. The main feature is the ease with which the brake notches can be modified to suit individual requirements ; further, the average braking bears a higher proportion to the maximum braking effort. The system employed up to the present time has had the minor disadvantage that once the values have been agreed upon they are not easily altered. Another advantage of the new system is that it makes possible a slightly increased output from the motor, due to a reduction in heating.

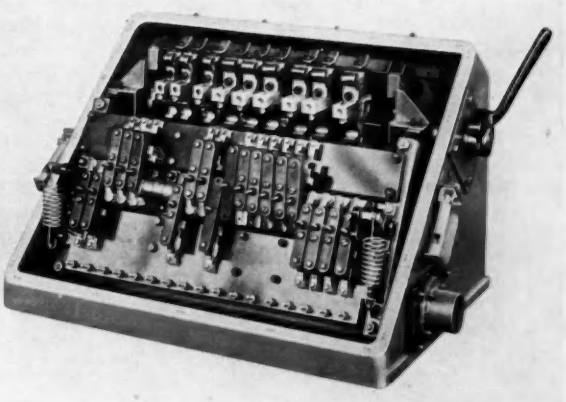


Fig. 23.—Master controller of the tappet type using butt contacts.

Railway Electrification.

An order has just been placed with the North British Locomotive Co. Ltd., by the South African Railways and Harbours Administration for forty 3 ft. 6 ins. gauge electric locomotives for mixed traffic service between Cape Town and Beaufort West. All the electrical equipment, to the value of approximately £1,000,000, is being supplied by the G.E.C.

The locomotives are considered to be the largest yet built for running on 3 ft. 6 ins. gauge. The control gear will be of the multiple unit type and provision will be made on the locomotives for regenerative braking on descending gradients. They will operate at 3,000 volts D.C.

The distance from Cape Town to Beaufort West is about 300 miles and gradients of 1 in 66 with a maximum of 1 in 50 are encountered. Passenger trains of 680 tons and goods trains of 1,200 tons will require to be hauled over this route, and the highest permitted speeds will be from 55 to 60 m.p.h. Twelve running speeds will be available ; the control equipment will be electro-pneumatic.

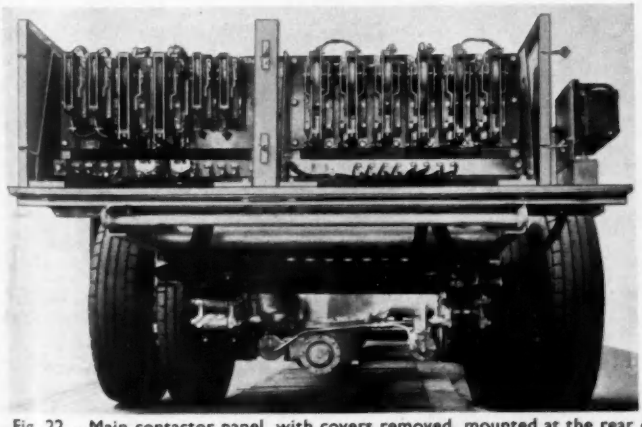


Fig. 22.—Main contactor panel, with covers removed, mounted at the rear of a British United Traction trolley bus, overseas type chassis.

During the period under review an order was received from the Sociedade Estoril, Portugal, for 1,500 volt motor coaches and a locomotive. This order is of particular interest in that it is the first for electric railway rolling stock ever to be placed with a British firm by a Portuguese railway, and was secured in the face of intense competition from continental manufacturers. The coaches, which are of all-steel

[1] "Electrical Progress and Development," *G.E.C. Journal*, Vol. XV, No. 1, February, 1948.

construction, are each mounted on two 2-axle bogies, the motor coaches being equipped with four 750/1,500 volt, 140 h.p. self-ventilated D.C. motors operating under electro-pneumatic control. The locomotive, which is required for mixed traffic, is of the double bogie type, each bogie having two axles which are fitted with 750/1,500 volt, 240 h.p. forced ventilated D.C. motors. The mechanical portion of the locomotive is being built by the North British Locomotive Company Ltd.

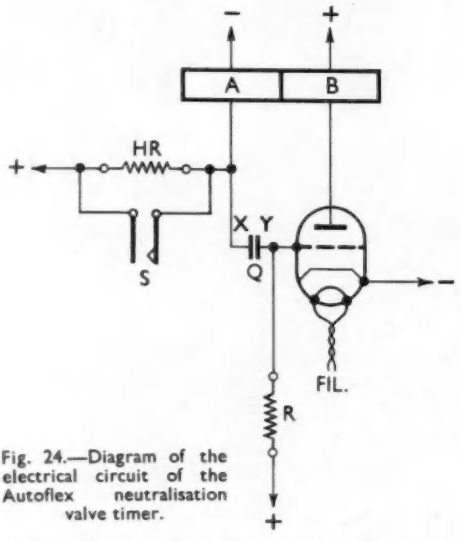


Fig. 24.—Diagram of the electrical circuit of the Autoflex neutralisation valve timer.

One hundred and fifty-six 600 volt D.C. motors are being supplied for the new surface stock of the underground railways of the London Transport Executive and will shortly come into service.

During the year work has begun again on an order for eight 3-car units for the British Railways to operate on the electrified section between Manchester and Glossop. This order was placed before the war by the London & North Eastern Railway Company, but the equipment to be supplied will embody all appropriate post-war development. Each unit comprises one motor coach, one trailer coach and one driving trailer coach. The motors are each rated at 220 h.p. one hour, or 160 h.p. continuous, 1,500 volts, and there are four per motor coach. The control gear is of the electro-pneumatic type and is mainly mounted in suitable cases on the under-frame.

Shortly before the war six battery-operated locomotives were supplied to the London Transport Executive for maintenance and constructional work on the tube and surface sections of the system. The most recent order received covers the supply of control equipment and batteries for a further seven locomotives. The arrangement is such that the locomotives can be employed for combined battery and third rail operation, together with automatic charging of the batteries from the third rail. Low-speed operation is a feature of these locomotives and a series, series-parallel or parallel combination is available with the four motors on each locomotive. This, in conjunction with several finely graded starting resistances, enables the equipment to meet all service requirements.

Vehicle-Actuated Road Signals.

In the Autoflex system of vehicle-actuated road signals, for which the Siemens and General Electric Railway Signal Company have been responsible, a changeover to a new method of timing has been made throughout the range of controllers which are needed to meet the widely varying traffic problems of to-day. Hitherto, timing of the various fixed and variable periods had been accomplished by the neon-tube/condenser/resistance method, which itself had been improved over the past 15 years by the designers of Autoflex.

Fig. 25.—Valve unit used with the Autoflex system, which is jacked into the controller pillar.

The neon tube method had certain fundamental disadvantages, amongst them being the need for a D.C. supply of at least 300 volts for satisfactory operation, this voltage having to remain constant within 2 or 3 per cent. The latter requirement has, in fact, necessitated the

use of a voltage stabiliser in each controller.

Now a thermionic valve timing circuit has been developed which enables all the timing requirements to be met with the use of 50 volts D.C., and which, moreover, is accurate in its timings under supply voltage fluctuations of ± 15 per cent. The cost of the valve, an Osram L.63, used in the new arrangement is a fraction of that of the neon tube used before, and the valve is expected to give long service by reason of the low anode voltage of 50 volts. The employment of low voltage has other advantages, in particular a great reduction in the strain imposed on circuit components. There will also be a reduction in the electrostatic attraction which in the old high voltage circuits gave rise to a deposit of dust, soot and "cobwebs" of the sort frequently found in the domestic radio set.

A diagram of the electrical circuit of the Autoflex neutralisation valve timer is shown in fig. 24. Relay *AB* is energised at coil *A* upon the closure of the switch *S*, which also renders electrode *X* of condenser *Q* fully positive. The electrode *Y*, in consequence of its connection to the valve grid, is held substantially at cathode potential; therefore the condenser becomes charged, electrode *Y* negatively with respect to *X*. To initiate a timed period *S* is opened, whereupon the potential of electrode *X* is reduced to the small voltage developed across coil *A* by the holding current through the resistance *HR*. The electrode *Y* now holds the grid negative to the extent of the supply voltage less the drop across coil *A*. The negative grid voltage is progressively modified by current flow through the timing resistance *R*, and eventually it passes through a zero condition allowing anode current to neutralise the holding flux in relay *AB* by its flow through the opposing winding *B*. The end of the timed period is signified by the release of *AB*.

There are three timing circuits of this type in the normal Autoflex controller for measuring the minimum green, maximum green and amber periods, also for measuring the speed of vehicles. Fig. 25 shows the valve unit which is jacked into the controller pillar.

The use of the low voltage timer has put the Autoflex system in advance of any other method either in this country or abroad. In due course it is intended to review in some detail the developments in road signalling which have taken place during the last ten years or so.

Frequency Correctors.

The signalling gear on the Southern Section of British Railways was designed for operation on 50 cycles and is sensitive to changes of frequency such as occur during load-shedding, that is, when at peak periods it is necessary to relieve the generators of excess load, and this is accompanied by a fall in frequency. To ensure that the frequency of the supply to signalling gear is sufficiently close to the normal 50 cycles under such conditions, it was decided to install the necessary plant to correct the frequency to within ± 0·5 cycle per second.

The frequency correctors or boosters consist fundamentally of A.C. motor frames with wound rotors. The stators have a normal three-phase winding which is connected to the three-phase 440 volt supply, the rotors have a single-phase winding designed to give a 440 volt, 50 cycle output.

The corrector is driven through gears by two

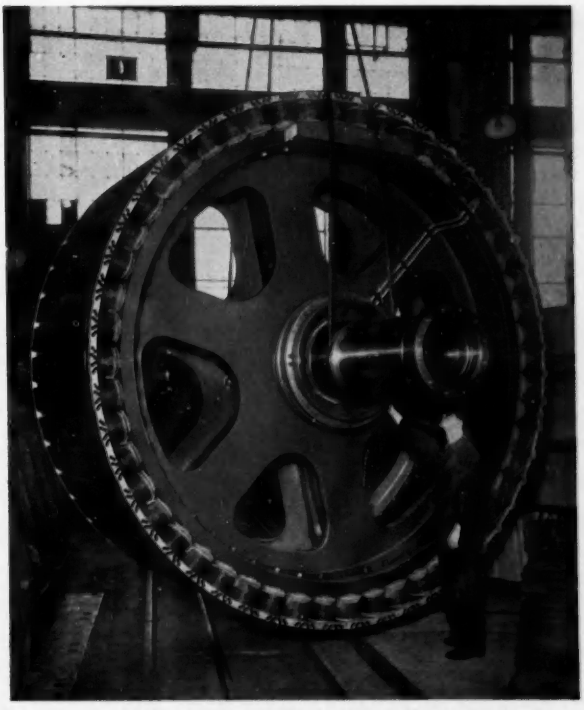


Fig. 26.—Magnet wheel of a 9,000 s.h.p. salient pole marine propulsion motor for the Eagle Oil & Shipping Co.

2-speed squirrel cage motors, one arranged to run at 1,500 r.p.m. or 750 r.p.m. (synchronous) with a gear ratio of 22·5 to 1, and the other at 1,500 r.p.m. or 500 r.p.m. (synchronous) with a ratio of 29·3 to 1. It is thus possible to drive the booster at approximately 16, 31, 48 or 60 r.p.m. and by driving it either against or with the stator field to boost or buck the supply frequency by approximately 0·5, 1·0, 1·5 or 2 c/s.

The booster is controlled by a frequency relay which, operating through a motor driven cam disc controller and contactors, starts up the appropriate motor to drive the booster at the speed required to correct the frequency when it differs from normal.

The output from the correctors is 10 kVA at 0·8 power factor which is corrected to unity power factor by condensers to improve the regulation; thus the actual output from the corrector is 8 kW, single phase, 50 cycles, 440 volts. These machines have now been completed and tested and the first is already installed.

MARINE ELECTRICAL EQUIPMENT.

Electric Propulsion.

The complete electrical propulsion equipment for a single-screw oil tanker built by the Furness Shipbuilding Co., Ltd., of Haverton Hill-on-Tees, for the Eagle Oil and Shipping Co., Ltd., has been supplied and installed during the past year. Further orders have been received for similar equipments for three more vessels of the same type now in course of construction. Each of these vessels is to have an overall length of 530 ft. and a 69 ft. beam with a deadweight tonnage of 15,000. The maximum guaranteed speed is $15\frac{3}{4}$ knots with a service speed of $14\frac{3}{4}$ knots. The propulsion motor will be a 3·3 kV salient pole machine, 9,000 s.h.p. at 124 r.p.m., supplied from a turbo-alternator giving an output of 6,930 kW at 3,230 r.p.m., 53·8 cycles. Auxiliary power at 220 volts is supplied by two 400 kW D.C. geared turbo-generators running at 1,000 r.p.,m. A magnet wheel for one of the propulsion motors is seen in fig. 26.

The H.T. control gear is enclosed in a steel cubicle and a simple control desk houses the low tension D.C. switchgear and instruments. Manoeuvring is effected by three controls (*a*) a lever actuating the H.T. direction switch through an oil servo-operated gear, (*b*) handwheel control of the starting sequence by direct mechanical operation, and (*c*) handwheel control of the turbine speed. These controls are mechanically interlocked to prevent incorrect operation.

An order has also been received for electrical propulsion equipment for a pilot tender. The vessel which is being built for the Mersey Dock and Harbour Board is 165 ft. long and has accommodation for some thirty pilots. She will have a variety of duties in connection with taking pilots to and from homeward and outward bound ships, and at times may stand off the mouth of the Mersey for periods up to a week. The propulsion equipment consists of a 920 h.p. single-armature propelling motor which is supplied with power from two tandem generator sets driven by National Diesel engines. The main generators are each rated at 375 kW, 360 volts D.C., the auxiliary generators at 80 kW, 220 volts.

Electrification of Auxiliaries.

Up to comparatively recent times all the auxiliary gear on drifters, trawlers and other vessels of this class has been steam driven, but the many advantages of electric drive are now being recognised. Apart from its simplicity and ease of handling, electric drive does away with the inconvenience and wastefulness of leaky steam pipes, and maintenance work is considerably reduced. It should also be borne in mind that the trend towards the use of diesel

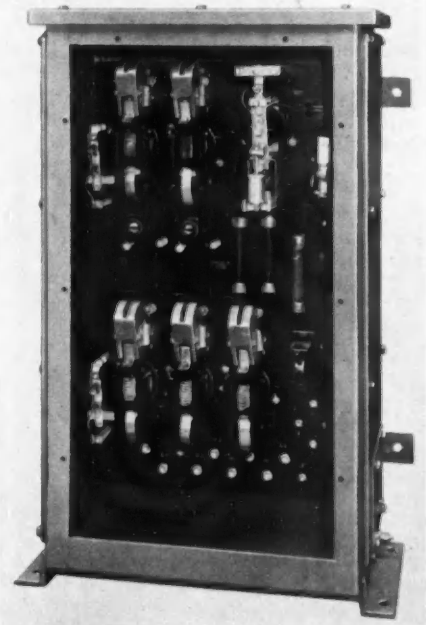


Fig. 27.—Interior of 5 h.p., 220 volt D.C. contactor cubicle for control of a capstan on a drifter.

engines for propulsion will require new means of driving auxiliaries.

A conveniently arranged system of electric motor drive and control has been developed and is being fitted to capstans for use on a number of North Sea drifter-trawlers. The motors are

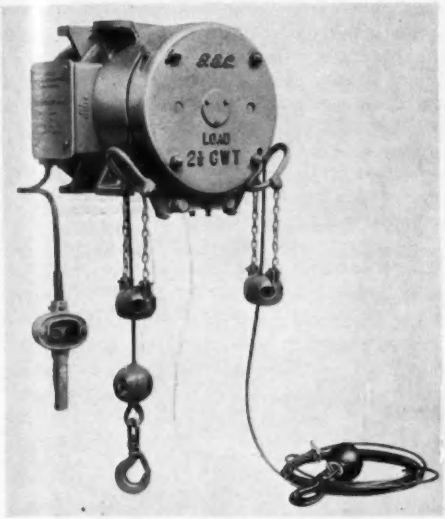


Fig. 28.—2½ kW double-acting hoist showing push button control and hoisting gear.

5 h.p., 220 volt D.C. series machines with a shunt speed-limiting winding and are housed in the base of the capstan. The maximum speed is 1,800 r.p.m. and the full load speed 700 r.p.m. The motor, which is non-reversing, is coupled to the capstan through worm gearing, is arranged to stall on heavy pulls and to accelerate again as the load is reduced. The contactor panel, illustrated in fig. 27, is housed below decks, the master controller being mounted on the top of the capstan.

Reconditioning of Ships.

It is worth recording that an important part of the work of the Marine Department has been concerned with the large scale reconversion and reconditioning of ships that has been necessary since the war. Such work, though not spectacular, has been of great value in the effort towards national recovery and has made heavy demands on the Company in the supply of lighting fittings, telephone switchboards, galley and pantry equipment and general accessories. In addition, many extensive overhauls of electrical machinery have been undertaken both on site and in the Company's works.

In many cases equipment of old design has been replaced, and all this work, with the labour and material involved, has had to be completed in a limited time and on a scale never experienced under normal conditions.

Some idea of the extent of the reconditioning programme may be gained from the fact that, in addition to the vast number of small ships needing to be refitted, work has also been carried out on the Queen Mary, Queen Elizabeth, Mauretania, Queen of Bermuda, Orion, Orontes, Andes, Alcantara, Rangitiki, Strathmore, Strathaird and Stratheden.

ELECTRIC MOTOR DEVELOPMENTS.

Fractional Horsepower Motors.

A new design of double-rope hoist has been developed, driven by a fractional horsepower motor, capable of raising a load of 2½ cwt. at a speed of 80 ft. per minute (fig. 28). Where a single-phase A.C. supply only is available the driving motor is of the capacitor type. The double-ended rope has a hook at each end enabling loading and unloading of the hoist to be done simultaneously with consequent saving of

Fig. 29.—9-inch propeller fan with terminal box incorporated in the mounting ring.

time. The hoist can be used for lifting through any reasonable height by the provision of a rope of suitable length. The electrical and mechanical gear is housed in a weatherproof aluminium alloy casing and includes a magnetic brake, limit

switches and contactor control. The brake is held in the " off " position electrically and in the event of current failure is applied automatically by a heavy duty compression spring. Control is by means of two push buttons arranged for single-hand operation, leaving the other free for guiding the load into position.

Fig. 30.—Speed regulator for propeller fan.

Two-way mounting is provided so that the unit can be mounted either above or below a steel girder or beam.

A new 9-inch propeller fan of improved appearance and efficiency has been introduced, which sells at a substantially reduced price, an important consideration particularly in face of growing competition in the export market.

A departure from conventional design, this fan has a die-cast aluminium mounting of neat, pleasing design which forms a blade guard in the shape of a grille over the fan aperture (fig. 29). A terminal box incorporated in the mounting ring enables the conduit or cable to be connected unobtrusively. The drive is by a new shaded pole-type motor with a die-cast aluminium rotor and a redesigned field system from which the " starting irons ", or magnetic slot wedges, have been eliminated. With an output of nine watts, the unusually high efficiency of 25 per cent and a speed of 1,350 r.p.m. are obtained with silence and with satisfactory starting and speed regulation. This performance contrasts very favourably with the customary efficiency of small motors which is generally in the region of 12 per cent.

A new series of speed regulators of neat appearance for A.C. propeller fans has also been developed which provide improved stability of speed control. Regulation of the speed of fans used for ventilation is required because it enables the movement of the air and the audibility of the fans to be controlled to suit varying conditions. Produced in three sizes for fans consuming up to 80, 200 and 500 watts respectively, these new AR-type regulators give speed reduction down to 50 per cent of full speed by reducing the voltage applied to the motor terminals. In the 80-watt and 200-watt sizes, which are for single-phase circuits, the reduction is secured by a series choke with a single-pole switch, giving four running speeds and an " off " position.

A new arrangement involving a circuit improvement not generally employed gives much greater stability of regulated speeds with motors of the permanent split, capacitor type by reducing the voltage on the running winding only, leaving the starting winding and the condenser connected across the full supply voltage.

The choke construction of the 80-watt size regulator involves an unusual iron circuit which is the subject of a patent application. The arrangement is such that the iron losses are mainly concentrated in $\frac{1}{16}$ inch mild steel yoke plates where they are readily dissipated. The construction is rigid, silent and economical, and the relatively high losses reduce the volt-ampere rating by bringing the voltage drop across the series choke more nearly into phase with that across the motor winding.

Fig. 31.—Sewing machine motor with foot control unit.

On three-phase circuits and for single-phase fans consuming between 200 and 500 watts, the voltage reduction is secured by an auto-transformer of the open delta type. A 5-pole 6-position rotary switch is used which, in the "off" position, disconnects both the motor and transformer windings.

As will be seen from fig. 30, these new regulators enclosed in die-cast aluminium cases are pleasing in appearance and compact in size: the 80-watt regulator is only 5½ ins. by 3½ ins. by 3½ ins. The switches which are fitted with moulded control knobs and a plated scale, have a snap action ensuring positive location of running speed and "off" positions.

The controller used with the domestic sewing machine motor has been redesigned. A foot-operated switch is employed (fig. 31) and the sliding contacts have been replaced by a series of spring contacts which are depressed by pressure of the foot on a stud. There are no moving parts except the stud and the flat spring contact plates so that the controller is virtually indestructible. The outer casing is a metal casting strong enough to withstand the rough treatment it is likely to receive in its normal position on the floor.

MECHANICAL HANDLING.

Reversible Vibrating Trough Conveyor.

The Sherwen electromagnetically operated reversible vibrating trough conveyor aroused considerable interest at the Mechanical Handling Exhibition at Olympia in July, 1948.

The usual arrangement with electromagnetically operated feeders or conveyors is to attach the vibrator at an angle of 20° to the deck. This gives a forward and upward movement in one direction and a backward and downward movement in the other. On the upward and forward movement the material is propelled forward, while on the return stroke the trough slips back from under it. Thus the direction of flow depends on whether the upward movement is developed on the forward or the return stroke.

By the use of two vibrators separately controlled, this upward movement can be arranged on either the forward or return stroke, one vibrator being responsible for the horizontal movement and the other for the vertical component. Each vibrator is operated through a half-wave rectifier and the amplitude controlled by a rheostat.

The direction of flow of the material in the conveyor is controlled by a changeover switch which enables the polarity of one rectifier circuit to be reversed. Thus in one case the two coils are each energised through the rectifiers from the same half wave, that is, the forward movement is in phase with the upward movement causing the material to go forward. In the other case the two coils are separately energised from alternate opposing half-waves and are thus out of phase with each other, that is, the return movement is now in phase with the upward movement causing the material to move back in the opposite direction. Fig. 32 shows the working model as displayed at the Exhibition.

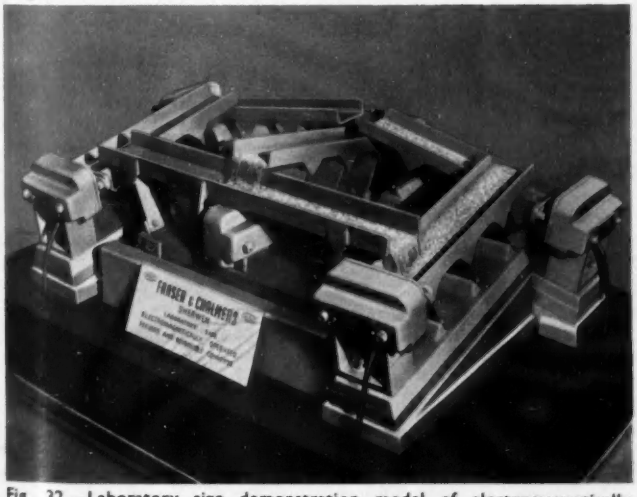


Fig. 32.—Laboratory size demonstration model of electromagnetically operated feeders and reversible conveyor shown at the Mechanical Handling Exhibition, Olympia, July, 1948.

Primary Jaw Crusher.

A large primary jaw crusher, having a receiving opening 72 ins. long by 48 ins. wide and weighing 140 tons, has just been completed for reducing quartzite rock in the copper mines of Rhodesia where it will operate underground at a level of 1,720 ft. The frame, pitman and swing jaw are of annealed open hearth steel with manganese steel jaw faces and cheek plates. It has a 12-inch setting and a capacity of some 440 tons an hour. Other settings are available to give outputs of 280, 310, and 350 tons an hour for settings of 8 ins., 9 ins., and 10 ins. respectively.

The machine is driven by a 250 h.p. motor, the power required being some 200 h.p. at 120 r.p.m.

The main crusher bearings

and pitman cap are water cooled and all journal bearings are lubricated from a mechanically operated grease pump ; oil lubricators are provided for the toggle joints. A shearing toggle is fitted which is designed to fracture in the event of tramp iron or other uncrushable material being encountered. There is a platform and staircase at the rear of the machine. Springs are provided under the pitman to balance its weight on the downward stroke.

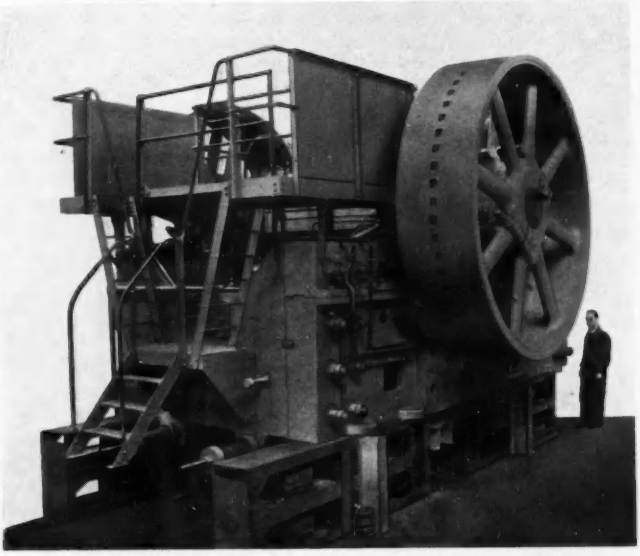


Fig. 33.—Primary jaw crusher with a receiving opening 72 ins. by 48 ins. for reducing quartzite rock in the copper mines of Rhodesia.

At the request of the client the crusher is specially equipped with an electric signalling system designed to function in the event of the cooling water supply failing or becoming unduly heated. All relays and lamps—with the exception of the no-float electrodes, water flow transmitters and thermostatic units—are arranged in one dust and weatherproof cabinet, controlled from a central point. A general view of the crusher erected in the Erith Works is seen in fig. 33.

Coal Preparation Plant.

Of the five coal treatment plants for export, either installed or on order, mention may be made of the new plant for the Tweefontein United Collieries, Ltd., Transvaal. This plant was put into operation early in 1948 and is capable of breaking and cleaning 400 tons an hour of run-of-mine coal. The larger pieces of coal are reduced to approximately 9 ins. in size by a pick breaker before being cleaned by the Chance Sand Flotation coal cleaning process.

Very accurate separating efficiencies are obtained with this difficult coal, there being on the average not more than 2 per cent of inferior coal left in the cleaned product and not more than 1 per cent of coal left in the discard.

This is the second installation at this colliery, the first having been operating successfully for the past 10 years. A general view of the plant is seen in fig. 34.

Two similar plants are now in course of manufacture for India and will be the first coal cleaning plants to be installed in that country.

Due to increased mechanisation in the coal industry, there has been a tendency during the last few years for the finer sizes of coal to increase in ash content and it has been found necessary to clean these so as to render them acceptable for steam raising and coking purposes. To achieve this there has been developed at the Erith Works a Froth Flotation system, as an adjunct to the Chance Sand Flotation process to clean the coal below $\frac{1}{16}$ in. size. Consequently it is now possible to supply coal preparation plant capable of treating the whole pit output in these two processes.

A recent order has been placed by the National Coal Board for the installation of such a plant at their Mansfield Colliery to treat 465 tons an hour of run-of-mine coal.

For controlling the coal handling, screening, picking and loading plant at Ffaldau Colliery, South Wales, a mimic diagram control board has been supplied. It is of welded sheet steel construction with lift-off dust-tight covers for mounting in the main screens house. The diagram is composed of continuously illuminated strips coloured and engraved in relation to the sequence interlocking scheme. Chromium-plated bezels indicate the pithead feeders, loading hoppers and conveyor cross-overs.

A four-position drum switch selects the sequence required and the position of the various flap gates is indicated on the diagram confirming beforehand the direction of flow selected. Each group of conveyors, interlocked to ensure correct sequence, is controlled by push buttons, and warning hooters sound automatically before any group starts. An indicating lamp on the board lights during this period.

A lock and free push button stops the whole system in case of emergency and a master start and reset button initially energises the control circuits.

The rear cover, normally locked, is easily removable for maintenance purposes. The ninety-four lamps employed are lit from a 50 volt supply taken from a transformer on the main board.

ELECTRONIC CONTROL.

Planer Drive Control.

An article on the control of the drive to a Loudon planer is published in the present issue. This machine has now been in service for about twelve months and the experience gained has shown that the method of reversal, during which the rectifier functions as an inverter, is highly satisfactory. This demonstrates that, suitably controlled, an inverter is a reliable piece of plant: a fact of great importance in many other branches of electrical engineering.

One of the particularly successful features has been the feed system which, by avoiding the use of mechanical devices attached to the planer body and so allowing the feed control to be placed on the control desk, has greatly simplified setting and adjustment.

Electronic Control of a Capstan Lathe.

A system of electronic control has been designed and built for the drive to the main spindle of a capstan lathe. The driving motor is rated to deliver 5 h.p. at 1,500 to 3,000 r.p.m. with control of speed down to 60 r.p.m., the maximum torque remaining constant. The whole range of speed is obtained by control of armature voltage using six vapour-filled triodes in six-phase. The speed control is arranged to be level from no load to full load at 60 r.p.m. and droops by 2 per cent at 3,000 r.p.m. Three speed-presetting potentiometers are provided and by means of a rotary switch on the lathe the spindle may be changed to any one of the three preset speeds. Armature current control enables the machine to be run up or reversed with the minimum loss of time and without mechanical or electrical overstress. Reversal from 3,000 r.p.m. in one direction to the same speed in the opposite direction is achieved in less than 6 seconds. The cubicle for the electronic control of a capstan lathe is seen in fig. 35.

A special system of automatic dynamic braking is incorporated which operates whenever the

Fig. 34.—Coal preparation plant at Tweefontein United Collieries, Transvaal.

speed is reduced, the braking being automatically tripped as soon as speed reduction is discontinued.

Other Applications of Electronic Control.

Contracts are in hand for the manufacture of suitable equipment for the electronic control of two 100,000 lb. drawbenches and three 25,000 lb. drawbenches. The power supply to the driving motor will be provided by a grid-controlled pumpless steelclad mercury arc rectifier which will be electronically controlled to give an adjustable output voltage that will remain substantially constant from no load to full load at any set value of voltage.

Another interesting application for which an order has been received is the electronic control of a rotary printing press. Here again power will be supplied by a grid-controlled pumpless steelclad mercury arc rectifier. The electronic control of the rectifier will provide a supply to the motor that will enable the speed to be controlled from crawl speed up to printing speed, the speed being constant from no load to full load at any set value. In this way the need for a barring motor is eliminated. Control of the printing speed will be obtained by variation of the motor shunt field with maximum armature voltage. In this way the highest possible efficiency and power factor are maintained when printing.

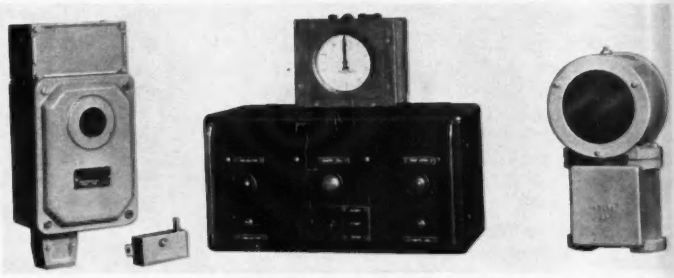


Fig. 36.—Photoelectric race timer for master control cubicle and timing clock.

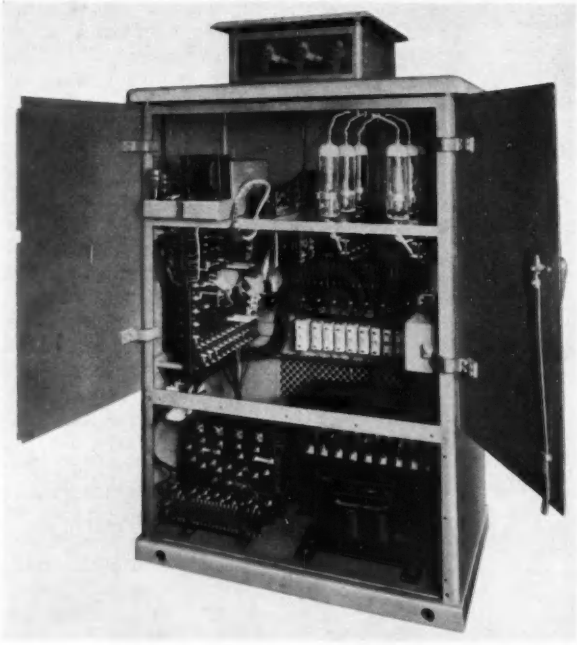


Fig. 35.—Cubicle for the electronic control of a capstan lathe.

Photoelectric Applications.

Daylight-operated Photoelectric Unit.

The photoelectric cell may be used very conveniently where it is desired to perform automatically a specific operation at sunset or sunrise. Common examples are the control of street or factory lighting, or aircraft warning obstruction lights on aerial masts, towers or other tall structures.

Photoelectric equipment for such duty must be of robust construction, weatherproof and with liberally rated components suitable for continuous duty with minimum maintenance. Failure of the equipment should result in the controlled circuit being switched to a " safe " condition which will normally involve closing the load circuit.

Due to the slow rate of change of incident light at dusk and dawn, it is important to ensure positive operation of the final relay which may otherwise be subjected to chatter of the contacts, with resultant unnecessary wear, quite apart from the undesirability of the load being repeatedly switched on and off.

This feature is incorporated together with provision for adjusting the sensitivity which can be done very simply and without removing the main cover.

Race Timing Equipment.

The unit illustrated in fig. 36 has been designed for timing a race where the start is initiated by a mechanical movement such as the opening of the trap for greyhounds or the release of the starting tapes for turf or speedway. This action starts the timing clock which makes one revolution of the dial every three seconds. On the last lap of the race a switch on the main control box is moved to the " finish " position. Immediately the invisible ray across the track at the finishing post is broken the timing clock is stopped, when the time may be read directly from the clock dial. The photoelectric unit incorporates a gas-filled relay valve to give the necessary high-speed response. The control box includes provision for manually testing the complete installation for correct operation from a central position without the need for inspecting each item independently.

TELECOMMUNICATIONS.

Radio Communication.

An outline of the extensive radio communication system for the new Middle East pipe line has already been published.[1] Work on this has continued throughout the year and a full-scale trial of the equipment is now in progress.

A 7-channel V.H.F. radio trunk has been set up between Wembley and Coventry over a route of 107 miles, using three intermediate stations. The F.M. equipment of new design accepts 7 + 1 channel carrier telephony signals from a standard type multichannel carrier bay.

The transmitter power may be 1 watt, 20 watts, or 100 watts, according to requirements. In the final equipment both transmitting and receiving aerials for go and return circuits are mounted on the same mast and give a directive gain of 14 db. and a beam width of approximately 26°.

Measurements of V.H.F. propagation between aerials at heights up to 300 ft. above the surrounding terrain have been carried out using a naval type of barrage baloon. Elaborate filters have been designed to prevent the transmitter power from interfering with the receiver operation. Equipment has been designed and built for survey purposes over any projected route.

In addition to these V.H.F. tests, problems peculiar to H.F. operation are being investigated over a radio link. These are mainly concerned with the connection of the radio link to the telephone system and arise as a result of the deep fading experienced on these frequencies.

Among new equipments developed during the past year is a larger H.F. transmitter. This covers a frequency range of 2 Mc/s. to 17 Mc/s. and gives a CW output of 1 kW. Remote control facilities provide an automatic selection from six preset frequencies, one of which may be obtained from a variable frequency oscillator.

Good stability is obtained by thermostatic control and careful circuit design.

The automatic selection is performed by a motor which rotates the tuning control to predetermined positions. Two electromagnetically operated clutches for each control allow clockwise or anti-clockwise rotation, depending on whether the required frequency of operation is above or below that of the original position. Tuning may also be performed directly from the front panel.

The transmitter is made either as a single unit, grid modulated, giving a modulated output of about 250 watts, or as a double bay unit, anode modulated, giving an output of 1 kW.

Improvements in the compact V.H.F. equipments have extended the frequency range to 184 Mc/s. to include the new band allocated to business radio.

Television Relay Link.

The development of the London-Birmingham Television Radio-Relay Link for the G.P.O. has continued. Steel masts, each 130 ft. high, have been erected at the four relay station sites

Fig. 37.—Overseas model auto-change radiogram for A.C. or A.C./D.C. mains. The receiver is a special 5-valve, all-wave set with bandspread tuning. The changer will play eight 10-inch or 12-inch mixed records.

[1] Osram Bulletin, Vol. 25, No. 2. June, 1948.

at Harrow, Dunstable, Byfield and Rowley Regis. These masts have been used for field tests over the route and will be used for the initial working of the system until the special relay towers have been erected. Two special terminal towers, each 100 feet high, designed

Fig. 38.—E1862, oxide coated cathode, common-grid triode amplifier.

by Pirelli-General Cable Works, Ltd., for fitting on the roofs of Post Office buildings in Central London and Birmingham, have now been erected and equipped with the highly directional paraboloid aerials for transmission to the first relay stations outside the two cities.

Transmissions of television pictures over a path representing a typical section of the route have been made. The transmitter and the receiver for these tests were development models of the equipment to be supplied for the London-Birmingham system. The pictures were generated at the Wembley Research Laboratories, using a television film-scanner of the type which has been described previously. The signals produced by the film-scanner were of the 405 line BBC form, which it was recently announced will be maintained as the British standard, and were of an extremely high quality. The tests on the radio-link apparatus were very successful in that there was no detectable difference between the pictures as generated and as received after transmission by the radio equipment.

Quartz Crystals.

Further development work has led to improvements in processing and mounting quartz oscillator crystals. These are now available in a variety of holders at any frequency from 4 kc/s to 14 Mc/s. Most frequencies in this range can now be had in evacuated glass envelopes which provide permanent characteristics in any climatic conditions. Some higher frequency crystals (above 5 Mc/s) are also being produced in a fully tropical miniature metal container with metal-to-glass seals for the connecting pins. Complete thermostatically controlled crystal units have been made experimentally in the B7G miniature valve envelope. On a small scale, X-cut quartz plates are now being supplied mounted for use as high power ultrasonic vibrators in the range of frequencies 300-1,000 kc/s. Work is in progress to extend this frequency range downwards by loading the quartz with metal. The long term research on the preparation of synthetic quartz is continuing in parallel with work on growing and applying other crystals which are possible substitutes for quartz, or in some applications an improvement on quartz.

Thermionic and Electronic Devices.

Valves.

In close collaboration with the M.O. Valve Co. work in the field of triode transmitting

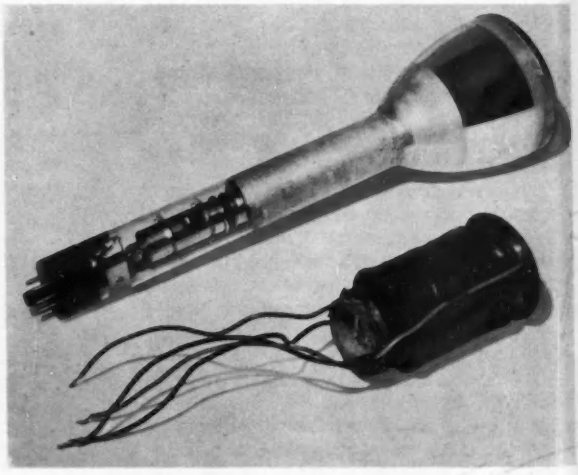


Fig. 39.—Projection tube for 11 inch Schmidt optical system.

valves continues to be directed towards the production of higher powers at the shorter wavelengths and new types have been added to the range already available. The E1862 (fig. 38) is the largest oxide coated cathode common-grid triode amplifier so far made, and is designed to deliver 1·5 kW of radio frequency power at frequencies up to 300 Mc/s. The next step upwards in power is provided by the ACT26, which is a triode with a 5 kW dissipation, using a thoriated tungsten filament. This valve, whilst of suitable electrical design to give full output up to frequencies of 100 Mc/s, is at the same time of rugged construction for use in industrial heating equipment, and possesses the good emission reserve necessary for wide band television use. In the very high power class of valves, the E1872 represents a modernised version of the CAT17, in which new techniques have been applied to reduce the grid and cathode inductances, so that the valve is suitable for higher frequencies.

The development of the E1714, a low-noise-level triode for use in wide bandwidth receivers, is nearing completion and new techniques for the production of this " planar-grid " type of valve are being investigated. Production of the three types of sub-miniature valve for use in the new hearing-aid amplifiers has begun. The development of the small electrometer triode has been completed and its size reduced to 10 mm. diameter, which is the same as that of the sub-miniature valves.

Cathode Ray Tubes.

During the past twelve months the 9 inch television tube (type 6501) has become well established and is now available. Excellent life performance is being obtained. A modification of the type 6501 tube has a heater intended for series running at a current of 0·3 amp. In addition, a new tube similar to the type 6501 but with a screen diameter of 14 ins. is being made.

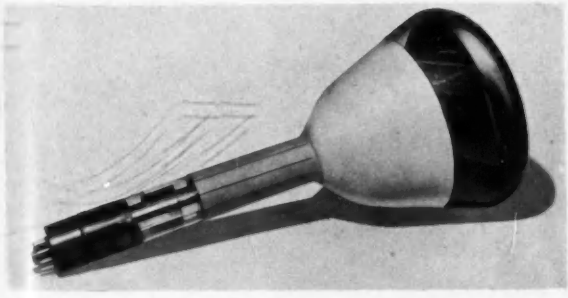


Fig. 40.—Picture signal generator tube of the secondary emission type.

Two special television monitoring tubes are being made in limited quantities. They are the experimental types 2211BXA and 1611HKM. The former is a precision electrostatically focused and deflected tube with a 9 inch flat screen which is used in positions requiring exceptionally high picture quality. The latter is a 6 inch flat screen tube which is magnetically deflected and electrostatically focused and has a small scanning angle. It is suitable for general monitoring and gives many of the advantages of a magnetic tube without the troubles associated with magnetic focus coils.

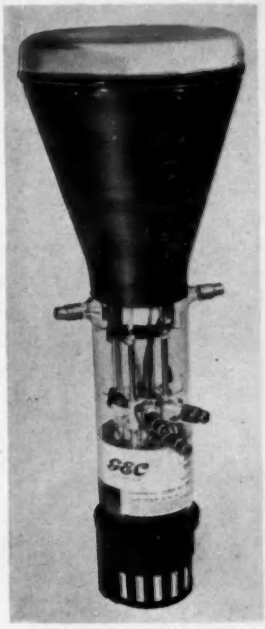


Fig. 41.—1608ABCA, special oscillograph tube.

Experimental projection tubes for use in the I.C.I. type 11/40 Schmidt optical system, fig. 39, have been made. These tubes incorporate a number of new features which include fluorescent screens backed with an aluminium film, an optically worked screen end joined to the body of the tube by means of a special glass with a low working temperature, and high tension contact taken through the screen join as a silver film. The tubes run at 25,000 volts and give a screen brightness of about 1,000 e.f.c. with adequate definition.

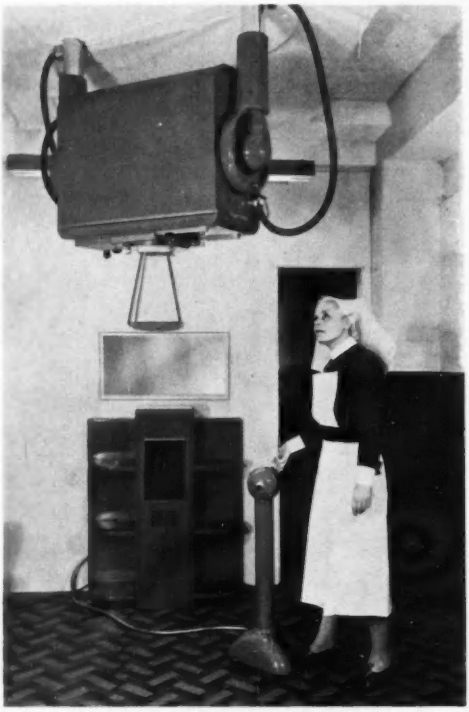


Fig. 42.—Watson and Sons (Electro-Medical) Ltd. deep therapy apparatus.

A new venture is a monoscope tube which is a picture signal generator of the secondary emission type (fig. 40). The picture plate is 100 x 80 mm. and has a maximum overall vertical definition of 800 lines. The tube will supply a picture signal containing frequencies up to 5 Mc/s when worked into a suitable load resistance.

An addition to the special oscillograph types of tube is the 1608ABCA shown in fig. 41. This combines the high single transient writing speed of the type 908BCC, on which 20,000 km/sec. has been recorded satisfactorily, with a greatly increased plate sensitivity. This is achieved by the use of multiband post deflector acceleration.

X-RAY EQUIPMENT.

A full programme of development work on X-ray and electro-medical apparatus has been undertaken in theWatson department of the Union Works in close collaboration with the Research Laboratories on behalf of Watson and Sons (Electro-Medical) Ltd. An important outcome of this work, which has recently passed the development stage, is a high voltage apparatus for use in deep X-ray therapy in which many original features are incorporated.

The new apparatus, known as Watson deep therapy apparatus type XT-1, is introduced at an opportune moment when, under the National Health Service Act, it is proposed to set up centres throughout the country for the treatment of cancer.

The tube-head with its motor-driven supporting mechanism is shown in fig. 42. It has an output of 250 kV, 18 mA, and yields a dose rate of 50 roentgens per minute at 50 cms. focus skin distance free-in-air with a half value layer of 1·5 mm. Cu. An important feature of the tube head is its relatively small size and weight as compared with apparatus of this type which has previously been available.

This result has been achieved by the use of a radically new circuit arrangement, in which only about half of the 250 kV peak is generated inside the tube-head itself, the remainder being generated by two high voltage rectifier units which, in the case of the installation illustrated, are situated in a room immediately above the treatment room. Connection of the two external units to the tube-head is by means of two shock-

Fig. 43.—Control unit for deep therapy apparatus.

proof cables, each subjected to only one quarter of the total tension.

The target of the X-ray tube is oil-cooled by means of a specially developed pump and cooler which is so constructed that there is no possibility of the oil becoming contaminated with water. These elements are housed with other auxiliary gear in the same room as the high voltage rectifier units.

In the model illustrated, the tube-head is carried on ball bearings between the lower ends of two vertical columns suspended from a large ballrace in the ceiling. The vertical movement is motor-driven and controlled by a mobile pedestal with two-way control. Where the structural work involved in the installation of the ceiling-mounted model cannot be undertaken, a floor-mounted version will be offered as an alternative.

Fig. 43 shows the control unit, which is so designed that the operator seated at the control can readily see over the top through an X-ray protective window into the treatment room. The controls are interlinked in such a way as to minimise the risk of causing injury to the patient. For example, tension cannot be applied to the tube until the cooling system is working correctly and the operator has checked that the correct filter is in position.

A monitor ionisation chamber is permanently fitted in the path of radiation on the patient side of the filter and is connected to a robust galvanometer mounted in the control, thus enabling a check to be maintained on the consistency of the dose-rate during treatment.

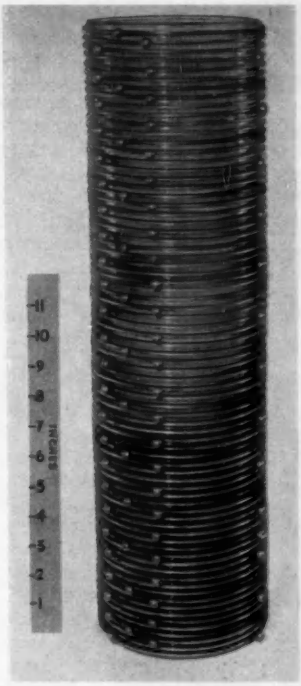


Fig. 45.—Section of accelerator column showing corona rings and high voltage connectors.

An inter-communication loudspeaker system is embodied enabling the patient and operator to speak to each other, whilst an extension microphone/loudspeaker is installed in the transformer room for the use of service engineers.

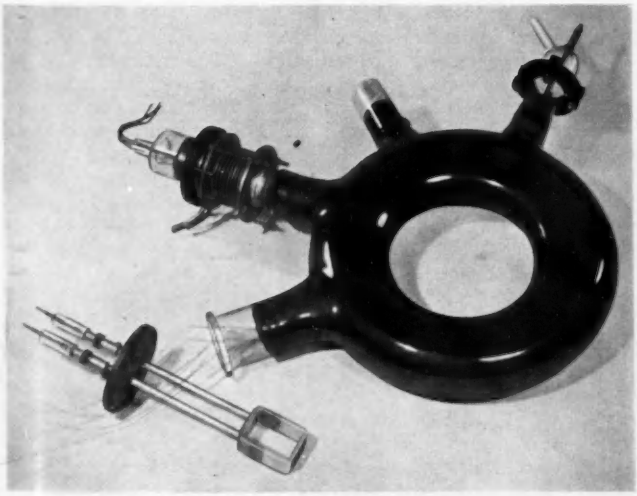


Fig. 44.—30 MeV synchrotron " doughnut ". Equilibrium orbit, 10 cm. radius. R.F. resonator is shown withdrawn on left.

ACCELERATORS.

Development work at the Research Laboratories for Atomic Energy Research Establishment under the auspices of the Ministry of Supply has included the provision of vacuum chambers for synchrotron machines, and experimental work on accelerator columns for use in conjunction with the Van de Graaf generator.

The acceleration of electrons by combined betatron-synchrotron action takes place in

an evacuated annulus or " doughnut ". Techniques have been developed for the ready fabrication of these annuli in glass to close dimensional tolerances on the shape of the section. Two sizes, for the acceleration of electrons to energies of 12 and 30 million electron-volts, are produced from the familiar 9 inch magnetic cathode ray bulb by a combination of blowing and tooling. Each annulus is provided with side-ports for evacuation and the insertion of a three-electrode gun, a radio frequency resonator and a target for the production of X-rays (fig. 44). Some of these machines are for the use of the Medical Research Council. New constructional techniques are being developed for much larger chambers for 140 and 300 MeV synchrotron machines. The programme includes development work on electron guns for injection voltages up to 100 kV.

For the accelerator column, specimen sections about 22 ins. long, five of which make up a complete column, have been prepared by fusing together alternate glass and copper rings. The glass rings are approximately $\frac{1}{4}$ in. thick, $4\frac{1}{2}$ ins. bore and $5\frac{1}{4}$ ins. external diameter. The copper rings are ·014 in. thick and overlap the glass slightly, both internally and externally, to provide concentric internal electrodes, which are connected externally to the high voltage potentiometer with suitably designed connectors and safety spark-gaps (fig. 45). The components of a section are assembled inside an oven and the sealing together is effected by moving the assembly through a fixed eddy current heating coil.

The column operates in an external gas pressure of 400 lbs./sq. in. while being highly evacuated on the inside.

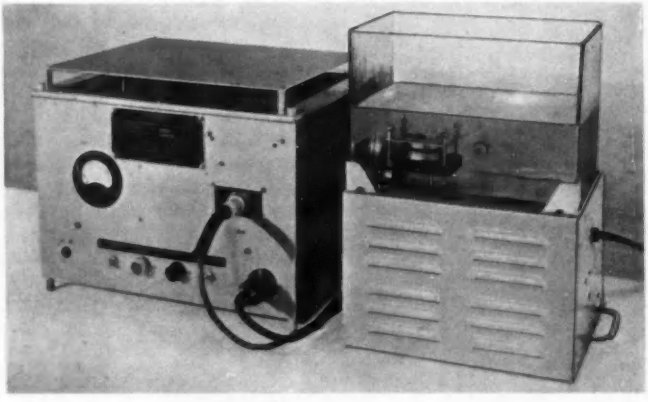


Fig. 46.—100 watt ultrasonic generator unit for exploratory work.

MEASURING INSTRUMENTS.

The possible commercial applications of ultrasonics can be divided into two main groups :

(*a*) Processing. Examples include the preparation of emulsions and the destruction of bacteria.

(*b*) Measurement and signalling. Examples include the determination of metal thicknesses, flaw detection, underwater signalling, and the measurement of the behaviour of materials during ultrasonic propagation.

In all cases, preliminary experimental exploration is required to establish in what directions commercial applications are likely. Yet the range of experiments is so large that it has only been possible actively to examine a few cases.

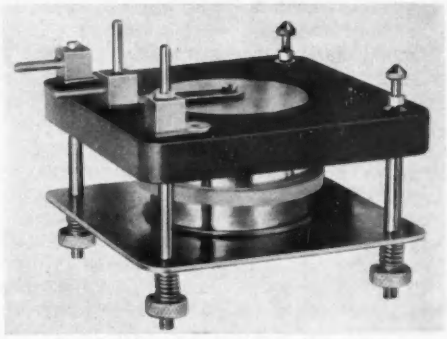


Fig. 47.—Quartz crystal transducer unit.

The alternative is to provide an experimental tool that will allow investigators to carry out their own exploratory work. Thus for processing investigations a 100 watt generator has been developed and is in small scale production.

This equipment works at one of three spot frequencies, 300, 650, and 1,000 kc/s, selected by interchanging coil units, no further adjustment being necessary. The oscillator unit is shown in fig. 46, and the quartz crystal transducer unit in fig. 47. The equipment is protected by the usual safety switching.

The measurement of thickness of materials by electronic methods is a problem which has received considerable attention. For example, in paint spraying and plating processes it is often necessary to measure

the thickness of a non-magnetic, conducting or insulating material on a magnetic base. An instrument for such measurements has been available for some time, but is now superseded by a

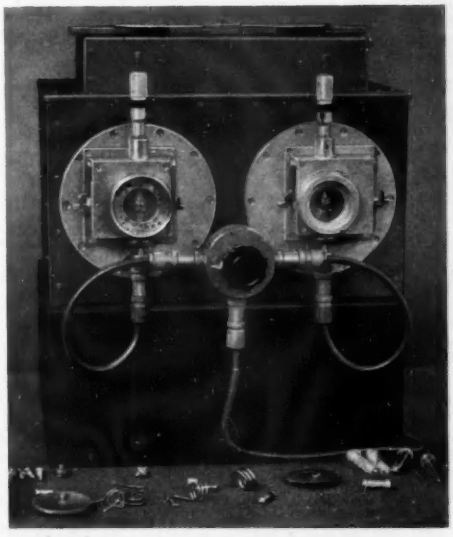


Fig. 48.—Impedance measuring gear.

superior model. The new instrument can be used in such a way that it maintains its accuracy of measurement to within ± 10 per cent over the whole scale of 1 to 45 thousandths of an inch for considerable variations of mains input voltage, range of temperatures, and for different types of magnetic base material. Ability to accommodate materials of different permeabilities is of extreme importance in the general utility of the instrument.

In the last review published in this Journal, brief mention was made of an experimental impedance measuring set which was then in development. This equipment, seen in fig. 48, has proved useful in investigations on coils, valves, cables, etc. The frequency range is 30 to 500 Mc/s, and the impedance range is 1 to 100,000 ohms in a single range to within an accuracy of 5 per cent.

To facilitate measurements of aerials and similar impedances, a high frequency bridge has been designed for operation in the region of 30 to 100 Mc/s, and for impedances around 75 ohms. One experimental model is in development.

The general measurement of illumination demands an instrument which will deal with subjects as far apart as street-lighting and interior lighting. A general purpose illumination meter has been developed to fulfil this need. Its ranges are 0-3, 0-15, 0-30 and 0-150 lumens/sq. foot and each scale is linear. The sensitive element consists of four rectifier type photocells which are contained in a unit separate from the meter. This cell unit is complete with viewfinder and provision is made for attaching a levelling screw.

A second model, fig. 49, a pocket illumination meter, has been developed with a logarithmic scale of maximum reading of 150 lumens/sq. ft.

In an entirely different field, that of the medical use of X-ray therapy, demands have come for equipment to measure the output from X-ray installations. The problem fell naturally into two parts.

In the first place an instrument was required for use by hospital personnel to measure the total X-ray "dose" received by the skin of a patient under treatment. Fig. 50 shows the apparatus developed for this purpose. A small

Fig. 49.—Pocket illumination meter.

thimble ionisation chamber of $\frac{1}{4}$ cc. volume is placed where the X-ray dosage is to be measured. The feeble ionisation currents generated by the X-rays are measured by a sensitive D.C. amplifier. The instrument may be operated from the 230 volts A.C. mains with an overall accuracy of ± 1 per cent.

Secondly, physicists working in radio-therapy departments of hospitals required instruments to determine the output from their X-ray sets prior to treatment of patients. An exact knowledge of the X-ray field strength enables the correct positioning of the patient and filtration of the X-ray beam to be calculated, so that deep-seated diseased organs may be given the appropriate X-ray dosage. Suitable equipment has been developed in co-operation with Mr. L. A. W. Kemp, physicist at the London Hospital. The

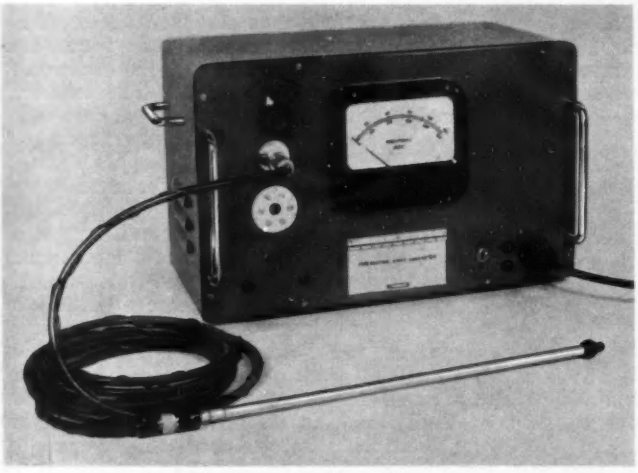


Fig. 50.—Integrating X-ray dosemeter.

" Kemp X-ray Comparator " is suitable for the rapid measurement of the X-ray absorption characteristics of various filtrants. The " Kemp Isodose Tracer " will draw a set of curves representing lines of equal dosage in a water phantom simulating the human body, irradiated by the specific set-up of X-ray tube, applicator and filter which it is proposed to use on the patient. Such a " map " indicates to the doctor the " high " and " low " regions of X-ray intensity inside the body of his patient, and enables him to direct the X-ray beam accordingly. The equipment is semi-automatic in its operation, and enables correct measurements to be taken even under conditions of fluctuating radiation intensity from the X-ray generator, a circumstance only too often met with in practice.

X- and gamma-rays, besides being used therapeutically for medical purposes, may be unwanted by-products in much of the nuclear physics research now being carried out, and their intensity, if unchecked, may prove dangerous to the health of the workers. Alpha- and beta-particles, from nuclear physics plant and the many radioactive isotopes used for biological " tracer " work, fall into the same group of radiations.

All these particles and rays have the common property of ionising matter, which may be used for their detection and measurement. One of the best-known devices constructed for this purpose are Geiger-Muller tubes and fig. 51 shows an instrument which has been designed around the G.E.C. tubes types G.M.2 and G.M.4. Its primary applications are the relative assaying of isotopes and the surveying of radiation field intensity for health protection of working personnel. The design has the advantages of portability, compactness and lightness. The instrument measures 9 ins. x 6 ins. x 3½ ins. and weighs 7 lbs.; it is self-contained, operates from standard dry-batteries, and information regarding radiation intensity is given to the user both aurally and visually. In the former case, clicks are heard in the headphones whenever the Geiger-Muller tube is ionised and the recurrence frequency of such clicks gives an indication of radiation intensity. Simultaneously, a meter on the instrument shows a dial reading calibrated in " counts

Fig. 51.—Portable radiation meter. Geiger-Muller radiation meter in use for detecting radioactive filtrates.

per minute", four overlapping ranges extending from 60 counts per minute to 60,000 counts per minute. The aural information is of greatest use in a rapid field strength survey, while the calibrated meter reading provides accurate data for recording and subsequent comparison purposes.

The short lamps are preferably operated two in series on 200 to 250 volt supplies, thus enabling a choke coil of minimum size to be used. These lamps may be operated singly on high voltage supplies, but the choke is then necessarily much larger than for series operation. Single operation on low voltage mains, 100 to 130 volts,

Fig. 52.—Decorative cold cathode fluorescent units installed in the Rendezvous Café, Salisbury.

DISCHARGE LAMPS AND THEIR APPLICATION.

Much of the past year's work has been devoted to the development of new ratings of fluorescent lamps. In addition to the well-established Osram 80 watt 5 ft. and 40 watt 4 ft. lamps, there are now available 40 watt 2 ft., 30 watt 3 ft., 20 watt 2 ft. and 15 watt 18 in. lamps. Also, a range of lamps, 8 ft. long, varying in wattage from 50 watts to 125 watts, was marketed on January 1st, 1949.

Electrical and luminous performance data for these new ratings are given in the table on page 40, from which it will be noted that the range of lamps can be divided into two main classes: a higher brightness, higher loading class based on the original Osram 80 watt 5 ft. lamp, and a lower loading, lower brightness class of which the progenitor is the Osram 40 watt 4 ft. lamp. The various sizes and ratings have been devised and chosen to provide the lighting engineer with a wide range of lamps to meet the ever increasing variety of lighting problems which arise.

can be achieved with an economical design of choke.

It will be noted from the table that the new 8 ft. lamps are available in two diameters. The 1½ in. diameter lamp, operating at 125 watts, has the same current density and brightness as the Osram 80 watt 5 ft. lamp and should have many applications where a fluorescent lamp of high lumen output is required.

The 2 ft. 20 watt and 18 in. 15 watt lamps have been in use for transport and experimental applications but now that these are on the market they should have many commercial and domestic applications. The 2 ft. 40 watt lamps should also have uses where a high luminous output from a short length is desired.

A third colour known as "Natural" has been added to the existing "Daylight" and "Warm White" colours. "Natural" colour is generally similar in appearance to the present "Daylight" but gives a somewhat more balanced rendering of colours. The phosphor used for the new colour is one of the extensive range obtainable

from the halophosphate powders developed in the Research Laboratories and previously described in this Journal.[1] The table also gives the colours in which the various ratings, old and new, are available. In all, some 14 new types and varieties of lamps are being produced.

Fig. 53.—A corner of a lounge in the Royal Albion Hotel, Brighton, showing a cornice containing a line of 120 mA white and a line of 60 mA gold lamps. The ceiling fittings contain the same lamp combination, the current being 60 mA for both lamps.

After exhaustive tests the instant-start circuit for Osram 80 watt 5 ft. lamps, mentioned in the last Progress Article in this Journal, was marketed on October 1st, 1948. This arrangement embodies a circuit with a filament heating transformer and series choke similar in many respects to that used before the war for Osram floodlighting discharge lamps. Although, under favourable atmospheric and supply voltage conditions, the normal 80 watt 5 ft. lamp will start and operate satisfactorily on this circuit, it may sometimes fail to do so under adverse conditions. To meet these conditions, a special Osram 5 ft. lamp with a starting strip attached has been developed. The starting strip takes the form of an unobtrusive metallic conductor which is firmly attached to the glass envelope during manufacture of the lamp. It is vitally important that the starting strip should be thoroughly earthed and to enable this to be done it is joined to the shell of the cap at each end of the lamp.

Osram cold cathode fluorescent lamps have been used successfully during the year in many decorative lighting installations. Figs. 52 and 53 show effective applications of these tubes. A fluorescent cold cathode tube known as "Gold" has been introduced during the year, and gives a very warm orange light. This tube, which was developed and used on a small scale before the war, employs a basic neon discharge and a green fluorescent powder, giving a resultant orange light at an efficiency of 20 L/W. The lamp combines well with mercury fluorescent lamps to give a range of attractive warm sources having deep red colour rendering characteristics comparable with tungsten filament light, but with much better rendering of the blue end of the spectrum. These lamps have proved very successful for the lighting of restaurants and hotels.

[1] "The Luminous Performance of Fluorescent Lamps," by H. G. Jenkins and A. H. McKeag, *G.E.C. Journal*, Vol. XIV, No. 4, August, 1947.

ESSENTIAL CHARACTERISTICS OF OSRAM FLUORESCENT LAMPS

Length	Diam.	Watts	Initial* efficiency (100 hrs.) L/W	Available in these colours
8 ft.	1½ ins.	125	50	"Natural"
8 "	1½ "	75	50	
8 "	1 "	70	55	
8 "	1 "	50	55	
5 "	1½ "	80	45	"Daylight", "Natural" and "Warm White"
4 "	1½ "	40	50	
3 "	1 "	30	46	
2 "	1½ "	40	33	"Natural" and "Warm White"
2 "	1½ "	20	38	
1½ "	1 "	15	34	

* Refers to "Daylight" and "Warm White" colours. The efficiency of lamps in "Natural" will be some 8 per cent to 10 per cent lower.

In the application of fluorescent lamps to lighting problems, a number of fittings has been designed to meet special needs, in which new materials, in particular "Perspex", are finding increasing use. Fig. 54 shows special fittings, designed in collaboration with the Admiralty, for use in H.M. warships, having two Osram 2 ft. 20 watt fluorescent lamps in a totally enclosed diffusing cover of opal "Perspex".

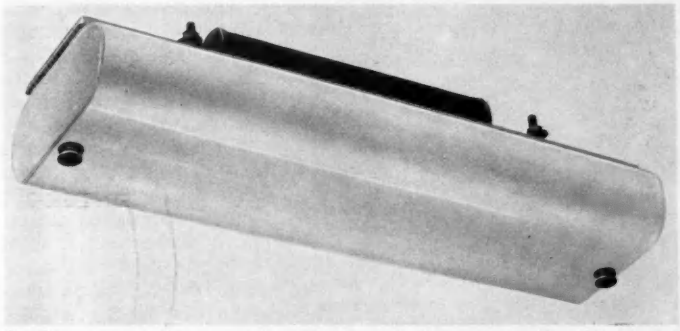


Fig. 54.—A special fluorescent fitting for use in H.M. warships. Two 2 ft. 20 watt lamps are accommodated in a totally enclosed diffusing cover of opal "Perspex".

Several new types of fitting for the long cold cathode lamps, using "Perspex" panels in various ways, have been designed. Examples have been illustrated in a previous article in this Journal.[1]

[1] "Practical Aspects of Cold Cathode High Voltage Lamps in Decorative and General Lighting," by C. Dykes Brown and K. S. Morris, figs. 12 and 18, *G.E.C. Journal*, Vol. XV, No. 2, July, 1948.

Interesting examples of the use of concealed fluorescent lamps are seen in fig. 55 and in the illustration, which forms the frontispiece to this issue, on page 2. The former shows a room in the Whitechapel Art Gallery, in which the pictures are illuminated by daylight fluorescent lamps in specular metal trough reflectors placed behind the beams. The latter shows the lighting of a church by concealed Osram 5 ft. 80 watt fluorescent lamps. Emphasis lighting of the altar is added by two Gecoray floodlights placed high up on the side walls.

There is an increasing appreciation of the value of fluorescent lighting in schools. An interesting experimental installation has already been made in a school classroom. The aim was to provide ample illumination on the desks while reducing glare to a minimum without the use of expensive diffusing fittings. The louvred ceiling fitting used was specially designed and is proving entirely satisfactory. Blackboard illumination is by means of an angle reflector using an Osram 80 watt fluorescent lamp.

For street lighting, in addition to the four-lamp lantern, smaller types to take three and

Fig. 55.—Whitechapel Art Gallery: "Daylight" fluorescent lighting. The fittings not in use are to light a central display when required.

Fig. 56.—Street lighting with four-lamp 320 watt lanterns in Marylebone Road.

two Osram 80 watt 5 ft. lamps have been designed for main roads. A series of lanterns for side roads has also been designed including a four-lamp 2 ft., 20 or 40 watt, vertical burning diffusing lantern.

Important new installations include Dioptrion high pressure mercury vapour lanterns installed at Portsmouth and a large installation of 140 watt sodium lanterns at Penge. Fluorescent installations include the lighting of the intersection of Marylebone Road and Baker Street, and the adjacent section of Marylebone Road, with four-lamp 320 watt lanterns (fig. 56). A further experiment on roundabout lighting in conjunction with the Ministry of Transport, has been made on the Oxford By-pass with cut-off lanterns (fig. 57).

Work on lighting for civil aviation has been described in a recent article in this Journal,[1] and the equipment here described is being further developed. Studies by the Royal Aircraft Establishment using the perspective plotting methods and dynamic models already described have resulted in a design for a new system of approach lighting, the Horizon Bar system, equipment for which is being designed. A prototype hand signalling lamp has been made for use on aerodromes.

[1] "Ground Lighting for Civil Flying," by H. J. Turner, *G.E.C. Journal*, Vol. XV, No. 1, February, 1948.

Experimental aerodrome identification beacons using special cold cathode fluorescent lamps are in course of development. These dissipate some 6 kW and give green light at intensities up to 20,000 candle power. These beacons can be made to flash the aerodrome identification in morse code at repetition rates of 15 or more per minute, if required.

To measure accurately the total light ouput from long mains voltage and high voltage fluorescent lamps, both alone and in fittings, calls for a large integrating photometer. Fig. 58 illustrates the 12 ft. diameter integrator now in use at the Research Laboratories. It is being used in conjunction with a Salford Universal Photoelectric Photometer. Ultimately the Physical Eye photometer and colorimeter[1] will be used with this integrator for the measurement of the colour appearance and colour rendering properties of tubular fluorescent lamps.

High pressure metal vapour compact source lamps of the 2½ kW and larger ratings have posed further problems in lamp design and application techniques. For the higher ratings, recent work has led to the improvement of quartz-metal vacuum seals which will carry currents of 300 amps. and greater. Seals to carry these

Fig. 57.—Cut-off lanterns used to illuminate a roundabout on the Oxford By-pass.

[1] "Electrical Progress and Development," *G.E.C. Journal*, Vol. XV. No. 1, February, 1948.

currents present many problems which had only been partly solved by the type of seal shown in fig. 59 (a).

Fig. 59 (b) shows a new departure in seal design which gives promise of being much more satisfactory than its predecessor In this new seal, currents up to 400 amps. are carried in a stout molybdenum rod of about 6 mms. in diameter. The rod could readily be made much larger so that the current carrying capacity of the seal is virtually unlimited. The seal would be made gastight by a thin diaphragm of molybdenum metal through which the rod passes and to which it is brazed. The outer edge of the diaphragm is embedded hermetically in the quartz and forms an effective seal.

The development of film studio lighting equipment using the 2½ kW and 10 kW compact source lamps has been carried further. Many experiments with colour film production, including a full-scale test of 50 units at the Shepperton Studios have been carried out. These have led to the approval by Technicolor Ltd. of the use of the 2½ kW lamp for the illumination of back cloths; some 60 units are also in use for this purpose at the British Lion Studios. Remote control gear for operating these units when slung high up in the studio has passed the laboratory stage.

The 2½ kW lamps are at present used only in a specially designed floodlight unit, but there is a spotlight unit in an advanced experimental stage. A 10 kW spotlight is under development which will serve a very useful purpose in place of, or in conjunction with, the 150 ampere high intensity arc lamps. Fig. 60 (a) and (b) show two views of this spotlight, the design of which presents problems not met in the floodlight. In the spotlight the lamp needs to be more completely enclosed for simmering and the shutters must not only clear the optical system in the open position, but must move to and fro with the lamp and mirror for focusing. Moreover, in this experimental spotlight, provision is made for restarting the lamp hot and for interlocking the electrical circuits and the door of the housing. The unit has already proved satisfactory in preliminary studio trials.

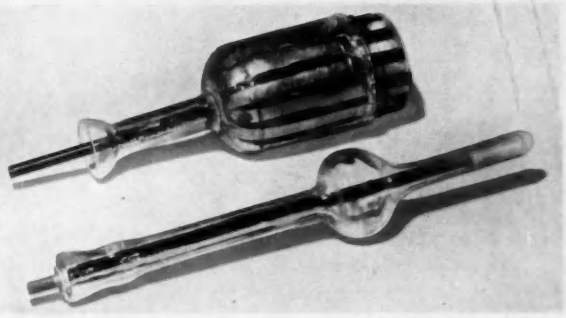


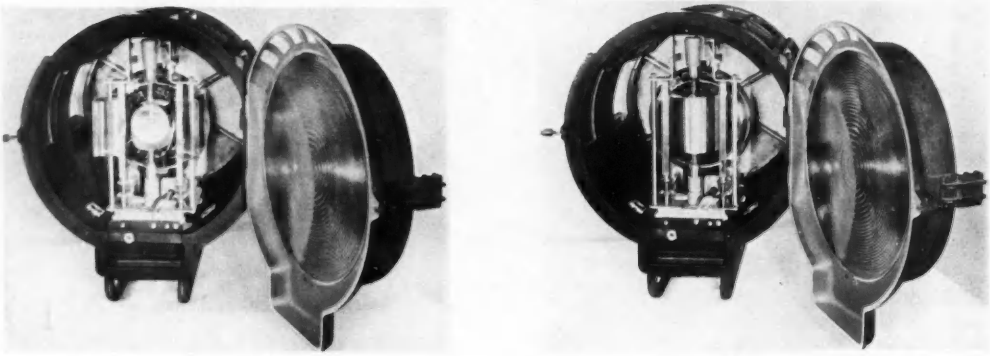
Fig. 59 (a and b).—Old and new types of quartz-metal vacuum seals.

A photographic lamp of a very different type is the 3 kW high pressure mercury vapour lamp for use in blueprinting machines, shown in fig. 61. This lamp is an efficient source of near ultra-violet radiation which, with its long life and freedom from moving parts, makes it a keen competitor of the traversing carbon-arc at present used for making blueprints and similar engineering reproductions. The lamp is an extended form of the well-known 400 watt HPMV street-lighting lamp. The arc length is 48 ins. compared with about 6 ins. for the 400 watt lamp, giving a rating of 3 kW. This length has been chosen to suit the largest size of blue-printing machine, in which prints up to 40 ins. wide are made. If the lamp is to be used in a machine

Fig. 58.—The 12 ft. diameter spherical integrating photometer for measuring fluorescent tubes up to 9 ft. in length.

or fitting where a fan is necessary to keep the surroundings cool, it must be enclosed in the glass jacket, as shown in the illustration. For many purposes the jacket will not be needed.

Work on the more conventional types of quartz high pressure lamp has led to the development of a 1 kW lamp of high intrinsic efficiency for use where high luminous output per fitting is needed. The general behaviour of the lamp is similar to that of HPMV lamps of the street-lighting type, and its colour rendering is slightly better than that of the 400 watt street-lighting lamp.



(*a*) (*b*)

Fig. 60 (a and b).—Experimental spotlight, using 10 kW compact source lamp, with shutters open and closed.

A totally different form of high brightness lamp having a point source is shown in fig. 62. This is an experimental version of a type of " Zirconia " lamp first suggested by the Western Union Telegraph Company. The source of light in this lamp is the end surface of a cylindrical rod of zirconia which is heated to incandescence by a discharge through argon at a pressure of about 1 atmosphere. The zirconia is embedded in a thick walled tube of molybdenum, or similarly refractory metal, which forms the cathode of the discharge. The anode is a plate of molybdenum drilled to enable the cathode rod and exposed surface of zirconia to be viewed through it.

The surface of the zirconia cathode in contact with the discharge operates at a temperature close to 3,000 degs. K. Evaporation is reduced to a negligible amount by the high pressure of argon used. At this temperature the brightness of the spot of light is approximately 6,000-10,000 candles per sq. cm., i.e. about 5 times as bright as the filament of the brightest tungsten projector lamps. The luminous efficiency is low—only a few lumens per watt—but this is not necessarily of importance in the optical projection applications for which this lamp is designed, where small source size and high brightness are the dominating requirements.

In the course of a single year, there arise very many new applications calling for discharge lamps of improved or novel design, of which only the most interesting and important can be mentioned here. There is, for example, the high pressure mercury vapour torch lamp shown in fig. 63 for use by the motion picture industry for taking night scenes. The lamp is made of quartz, and is operated at 125 watts and at an efficiency some three times that of a tungsten

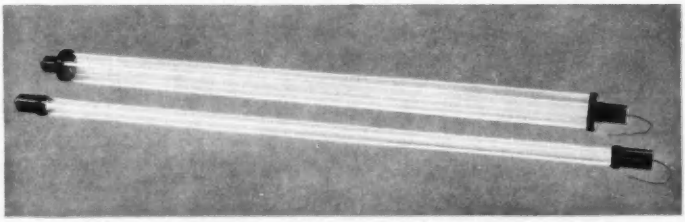


Fig. 61.—3 kW high pressure mercury vapour lamp for use in blue-printing machines. The optional loose glass jacket is also shown.

filament lamp. This very small but powerful light source can be fitted into an ordinary hand torch and gives a beam sufficiently intense to show up against the relatively high level of illumination on the set required when shooting night scenes.

Fig. 62.—Experimental 25 watt projection discharge lamp with zirconia cathode.

Although not "discharge" lamps in the accepted sense, it seems appropriate to mention here the new range of photoflash bulbs which will probably supersede the present range of Sashalites. The 'type SM', which is already available, has no metal foil but relies on increased quantity of primer paste to provide its 4,000 lumen-second flash of 10 milliseconds duration.

This small photoflash bulb is designed for use in due course with the new types of popular cameras equipped with synchronising contacts associated with the shutter.

In the category of "special lamps" comes also the thallium laboratory lamp which provides almost monochromatic radiation at 5,350 Angstrom Units in the green part of the spectrum.

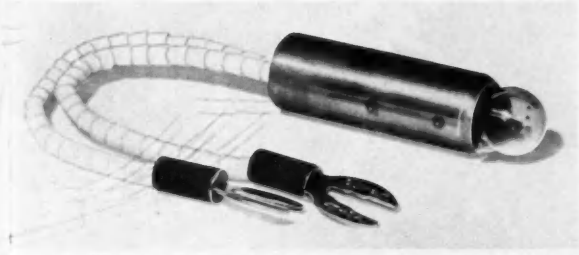


Fig. 63.—Experimental 125 watt compact source high pressure mercury vapour lamp, for use in night scene photography in motion picture studios.

PROCESS HEATING.

There has been a continuing demand for resistance furnaces for the heat treatment of ferrous and non-ferrous metals. Recent designs have included equipments for bright annealing steel strip, heat treating engine components, heating copper and brass billets for extrusion, continuous copper brazing (fig. 64) and for the bright annealing of 30 ft. long copper tubes. Controlled atmospheres are necessary for many of these processes and a new type of town's gas burner has been introduced with a capacity of 1,000 cubic ft. per hour which is more compact and gives easier accessibility and operation than earlier units.

Electric bread baking ovens are well-established items of bakery equipment. The recently installed 450 kW travelling oven in fig. 65 has fully automatic eight-point temperature control and is provided with an electrode boiler for steam injection. Interest in this equipment and in high frequency heating led the Research Laboratories to undertake an investigation, in collaboration with the Unilever Bakery Service, into the potentialities of high frequency heating for baking and allied processes. Some interesting results were obtained and as so many conflicting claims have been made in both technical and lay press about high frequency baking, it is worth recording some of the findings. It has been established that a loaf comparing satisfactorily in most respects with one produced by conventional methods can be baked in under five minutes (fig. 66). In preparing the dough, it is necessary to allow greater initial "proof" because baking is completed so quickly that there is little opportunity for the yeast to continue its normal work of producing gas during the baking process. The loaf has a good shape and normal crumb flavour, but nevertheless tastes differently because much of the flavour of bread is derived from the crust which, of course, is absent from the high frequency product. Plain and fruit cakes, too, have been

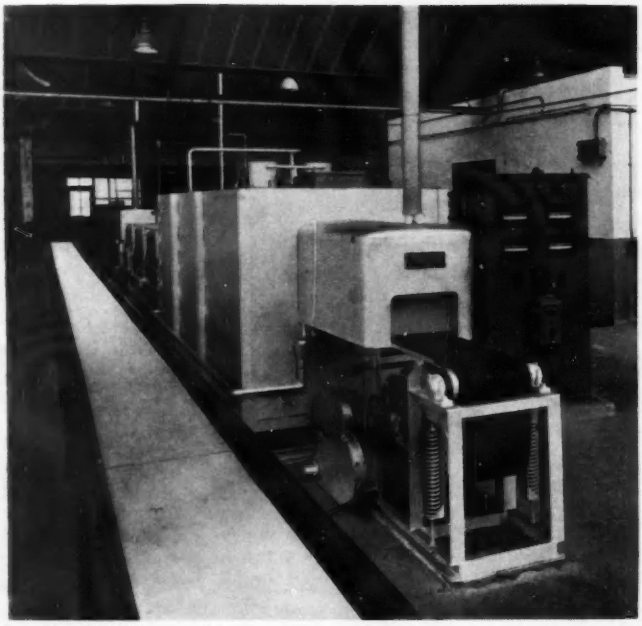


Fig. 64.—90 kW controlled atmosphere copper brazing furnace, used in the manufacture of refrigerator components. The operating temperature is 1,150 degs. C.

baked successfully (fig. 67), in times ranging from four to seven minutes. These results all apply to laboratory scale work in which a single loaf or cake was baked at a time. Many difficult technical problems would have to be solved before a commercial bread baking equipment could be designed. The economic aspects, too, would need to be considered and although at present accurate costings are not possible, the indications are that existing methods would prove appreciably cheaper.

Some subsidiary processes in the baking industry show greater promise, notably the melting of chocolate and fondant and the rapid thawing of frozen fruit and frozen eggs. Successful results have been obtained on a small scale with heating times of between three and five minutes.

A programme of work in collaboration with Morris Motors, Ltd. and others on the high frequency baking of foundry sand cores has brought some useful information. Core baking is normally carried out in ovens operating at temperatures of up to 300 degs. C. and requires times of one to two hours. With high frequency heating, cores ranging in weight from a fraction of a pound to a few hundred pounds can be baked in a few minutes. A

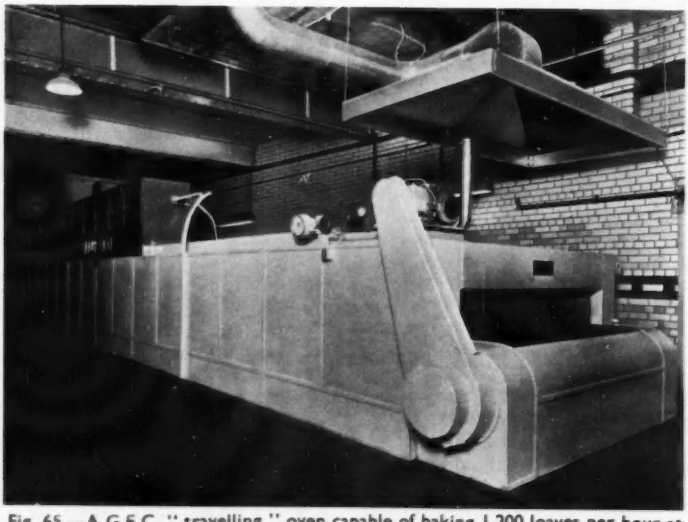


Fig. 65.—A G.E.C. " travelling " oven capable of baking 1,200 loaves per hour at the Bakery of St. Helens Co-operative Society, Lancashire.

satisfactory ten-pound core, for example, was produced in three minutes. Several bonding agents such as thermosetting resins and certain cereal binders and molasses-linseed mixtures are suitable. Interesting features are that cores varying greatly in thickness (up to 5:1) can be handled successfully between parallel electrodes and that there is considerable latitude in the positioning of metal reinforcing inserts within the core. Arcing occurs only when the ends of wires perpendicular to the electrodes come very close to the surfaces facing the electrodes.

Fig. 66.—A loaf of bread baked in 5 minutes by high frequency heating.

The wires need have no appreciable effect on the uniformity of the product.

The saving in processing time with high frequency heating can lead to considerable economies in floor space. Thus in a foundry where it is desirable, with existing methods, to have three or four hours' stock of all cores at the mould assembly stations to guard against shortages through breakage or absenteeism, the stock can be much reduced if high frequency equipment is available to provide replacements quickly in an emergency.

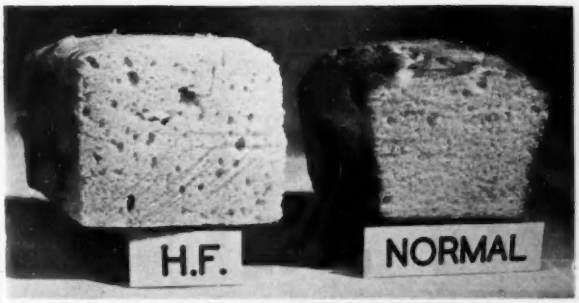


Fig. 67.—Comparison between a high frequency baked plain cake and a normally baked cake.

Fig. 68.—Condenser cans being fed on to a conveyor for automatic soldering by high frequency heating.

In the medium temperature field, several new radiant heating installations have been completed for processes such as paint stoving, the drying of printing inks, the gelling of polyvinyl chloride leather-cloth coatings, the softening of plastics and the drying of textiles, metal foil and foundry moulds. A horizontal high intensity radiant oven for stoving paint on refrigerator casings is seen in fig. 69. The horizontal oven with conveyor shown in fig. 70 is designed for drying china and earthenware cups, saucers and plates prior to firing and for drying the glaze coating which is subsequently applied.

DOMESTIC, INDUSTRIAL AND AERONAUTICAL APPLIANCES.

A new 5 cu. ft. domestic refrigerator (fig. 72), designed to meet both home and overseas requirements, is now in production at the refrigerator

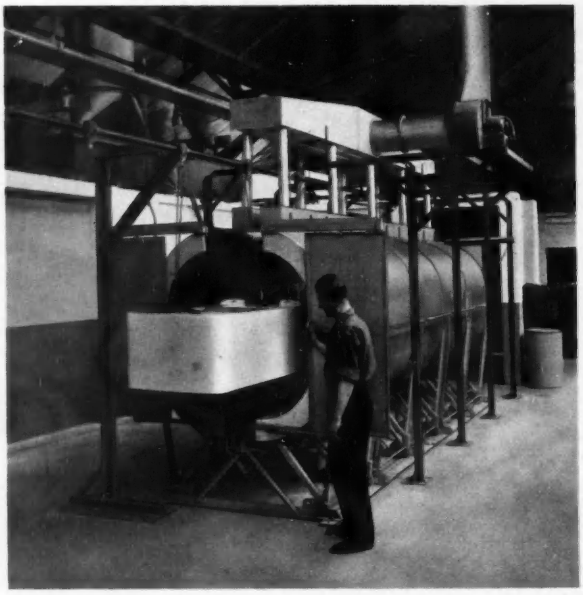


Fig. 69.—High intensity radiant oven for stoving paint on refrigerator casings.

factory at Wembley. It incorporates a hermetically sealed refrigeration system, the compressor, and the single-phase induction motor which drives it, being welded into a steel casing which prevents ingress of dirt and moisture throughout life (fig. 71). The motor is controlled by external starting and thermal overload relay. Elaborate precautions are taken to ensure absolute cleanliness during manufacture, all assembly operations and the subsequent tests for silence and efficiency being conducted in air-conditioned rooms maintained at constant temperature and humidity. The all-steel cabinet of the refrigerator is constructed on the wrapper principle in which the two sides and top are formed from a single sheet of steel. The back is welded in and the whole casing is sealed to prevent moisture reaching the insulation.

A group of post-war domestic appliances is shown in fig. 73. The aim in designing them has been to provide a pleasing modern appearance, coupled where necessary with improved technical qualities. Thus the kettle, which is much more attractive than the previous model, has a modified type of automatic safety release which projects very little outside the body and a semi-circular moulded " Bakelite " handle which can be grasped anywhere for lifting and pouring. The keynote of the toaster is simplicity. Formerly, toasters were difficult to clean and service. Now, by unscrewing two knurled nuts, which are only

Fig. 70.—Radiant heating oven in use for drying glaze on earthenware plates.

finger tight, the toaster can be dismantled completely, cleaned and as simply put together again. On the iron, the old-fashioned connector has been dispensed with and the lead brought direct to the terminal box in the handle.

There is a continuing demand for electric unit heaters for industrial space heating schemes. The heaters are now fitted with an improved bimetallic disc protector (fig. 74) which takes the place of the previous fusible link. If the fan fails, the current supply to the heater is interrupted before any harm can occur and can be restored only by pressing the hand reset button on the protector. Alternating currents up to 15 amps. are handled directly and heaters with loadings greater than 3 kW are controlled through contactors.

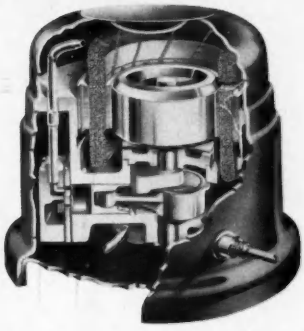


Fig. 71.—Cut-away section of sealed unit showing motor and compressor of the refrigerator, shown in fig. 72.

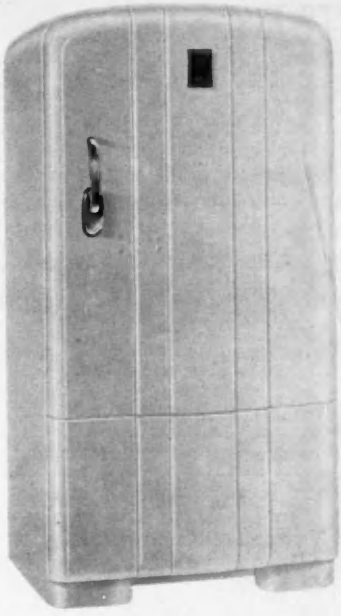


Fig. 72.—The new domestic refrigerator with a food capacity of 5 cubic feet.

Fig. 75 shows some of the equipment used in testing unit heaters to the specification agreed by the Unit Heater Manufacturers' Association. It includes an air flow measuring duct and hot wire and vane type anemometers for air flow measurements on small and large heaters respectively.

The air circulation oven shown in fig. 76 is used for heating pre-cooked frozen food on aircraft. Twenty-four meals, each containing a portion of entrée, potatoes and vegetables, are placed in the trays and are heated by sheathed wire elements at the sides of the oven. Air is directed over these elements by a built-in fan. The elements are controlled through a process timer which switches them off and rings a warning bell at the expiry of any desired preset period. A self-resetting thermostat prevents overheating by tripping the heater circuit when

Fig. 73.—A group of post-war domestic appliances.

the oven temperature reaches 230 degs. C. Light weight and low loading are essential requirements and have been obtained by making the oven of 20 gauge sheet aluminium and lagging it with 2 ins. of glass silk. The weight is 70 lbs. and the loading 2 kW at 24 volts. The oven will heat the twenty-four meals in 45 minutes from the frozen state or in 20 minutes from the defrosted state.

Fig. 74.—Improved bimetallic disc protector now fitted to unit heaters.

COLD PRESSURE WELDING.

A method of pressure welding at room temperature has been developed. Its chief application is to aluminium and its alloys, though other metals can also be cold-welded.

Two factors ensuring satisfactory welds are the preparation of the surfaces to be welded and the design of the tools used. It is well known that a film of oxide begins to form on aluminium immediately it is exposed to the atmosphere, but several days elapse before the film reaches its final thickness. Although thin, this film is sufficient to prevent welding.

In pressure welding the metal is caused to flow away from the welding point as the tools are brought together. The effect of this flow at the interface is to disperse the protective film on the material and so bring about metallic contact. Obviously more flow will be required to produce this contact if the film has reached its final thickness than if it is almost, or completely, non-existent. Thus in order to obtain satisfactory welds, it is essential that the surfaces to be welded are free from this contaminating film. The cleaning process should thus aim at exposing the bare metal by removing the film.

Fig. 76.—Air circulation oven for heating pre-cooked frozen food on aircraft.

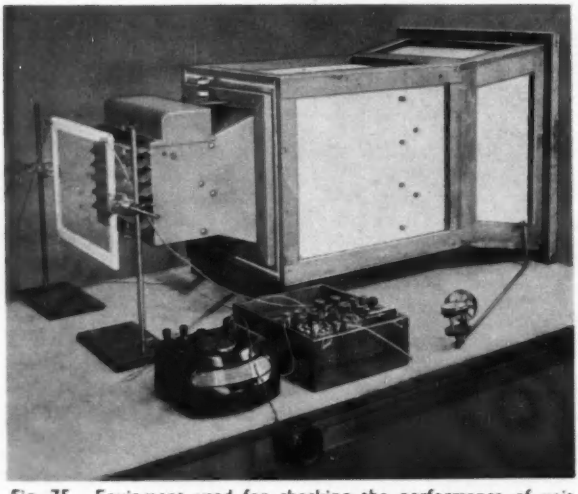


Fig. 75.—Equipment used for checking the performance of unit heaters.

The necessary removal of the surface oxide film is achieved by scratch-brushing with a steel wire brush rotating at a surface speed of 3,000 ft./min. Once the surface is cleaned, further contamination is avoided since that produced by a single handling may prevent a weld from forming.

Dies for commercially pure aluminium can be made of mild steel or from an unhardened chrome-manganese tool steel. Neither of these materials gives trouble with " pick-up " of aluminium, such " pick-up " as does occur being confined to a slight surface contamination which has the appearance of a thin plating.

Pressures required for aluminium are in the region of 12 to 18 tons per sq. in. which is only slightly above its

flow point ; the pressure required for copper is from two to four times this value. The shape of the tool is most important.

For spot-welding, rectangular indentations are superior to circular or square forms. Dies for making short rectangular welds (fig. 77) are mounted in a fly-press. The foreground joint shows the flow produced by the welds. The ease with which a metal may be welded is judged by the depth of indentation necessary to produce a satisfactory weld.

For commercially pure aluminium, this penetration leaves 30 per cent of the original double thickness. A carefully designed lay-out of welds enables the tensile strength of overlapping strip-joints to equal 90 per cent of the strength of the original strip.

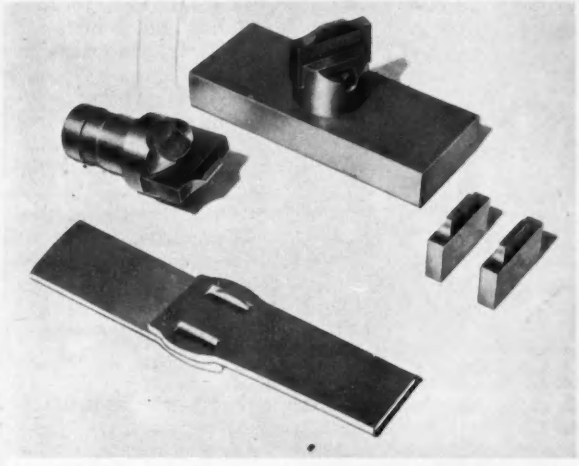


Fig. 77.—Dies for making short rectangular cold pressure welds. A weld made in this way is seen in the foreground.

Tools for cold-welding are simpler to design than those required for other types of welding. Heat resistant steels are not necessary and wear resistant steels are required only in occasional applications. Any die wear is counteracted by an occasional resetting of the die-closure.

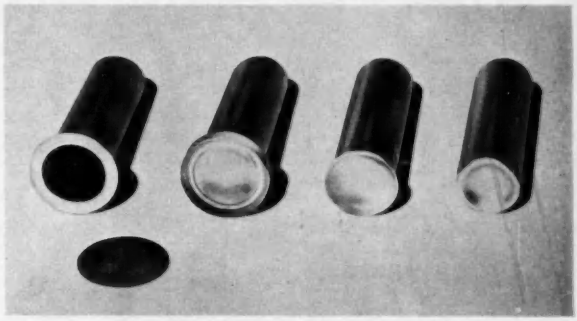


Fig. 78.—Ring type cold pressure welds.

Direct applications of the rectangular spot weld include the welding of busbar connections, joining handles to plates, etc. Overlapping wire joints can be made and a well-proportioned joint in copper or aluminium has a lower electrical resistance than an equivalent section of unjointed material.

Other important techniques developed include a long strip weld, which is useful for the side-seaming of cans.

The ring type of weld, made by circular tools, is used for capping containers (fig. 78), joining a flanged tube to a plate for making hose connections, or joining two discs together to make an air pressure cell.

The continuous seam weld has an important application in tube making. A machine has been constructed in which preforming, scratch-brushing, final forming, welding and trimming are carried out continuously and automatically. A roller-welding machine can also be used to seal the free edges of a folded box section, following an intricate outline if necessary.

Since it is possible to cold-weld, using a tool penetrating one face of the work only, it is possible to impact weld, using a hammer and punch. Small structures and boxes may readily be constructed by hand, using this method.

The Servo Electronic Control of a Large Planer

By S. H. DALE.

Electronics Section, Mercury Arc Rectifier Works, Witton.

A novel system of control for a large planing machine has been produced in the Mercury Arc Rectifier Works, Witton, incorporating the latest advances in servo electronic technique. The author describes the scheme and the equipment employed for a planing machine in the Witton Works, having a table 5 ft. by 14 ft. The electronic system shows important advantages in conversion efficiency, flexibility of control, ease of operation and saving of time.

THE problems of evolving a scheme for the static electronic control and power conversion for a large planing machine differ from those encountered in many other developments in the electronic field, because it has to compete with a well-established and effective system, which already exists in the form of the modern Ward-Leonard drive. Since the requirements are largely fixed by the nature of the machine, it was clear from the outset that the actual behaviour of the planer would be very similar to that obtained with the Ward-Leonard control. Nevertheless, certain important advantages could be expected, such as a higher conversion efficiency, greater flexibility of control and ease of operation, less waste time during planing, reduced mechanical stresses, and less maintenance time.

Provided that the maximum D.C. output voltage is not too low, the grid-controlled mercury arc rectifier provides a means of power conversion at once more efficient than the Ward-Leonard system and capable, by suitable grid control, of providing a variable output voltage, and also of accepting energy from the D.C. side and returning it to the A.C. supply. Further, the response of a mercury arc rectifier to a grid signal is practically instantaneous compared with the response time of the field of a D.C. generator, with its relatively high inductance and the eddy current lag of the iron circuit.

A planing machine with a 5 ft. by 14 ft. table, manufactured by the Scottish Machine Tool Corporation Ltd., was selected for trial of the electronic drive. This machine would normally have been fitted by the makers with a Ward-Leonard drive, but in this instance it was supplied with no electrical gear other than certain small limit switches on the tool holders. The electrical gear to be provided was as follows :

(*A*) Gear to be fitted to the planer itself.
1. Table stroke controlling limit switch.
2. Table acceleration switch.
3. Tool relieving solenoids (to lift the tool clear of the work during the return stroke of the table).
4. Two push button pendants.
5. Two emergency stop buttons and a cancelling push button for the tool holder limit switches.
6. The main reversing motor for driving the table.
7. The feed motor.

(*B*) Gear associated with, but not mounted on, the machine.
1. A control desk provided with means for making the necessary electrical adjustments to the operation of the planer.
2. A cubicle housing the converting plant, etc.
3. A rectifier transformer.

A general view of the planer with its electronic control equipment is shown in fig. 1.

The power and control circuits fall into three main groups, namely :

(*a*) those associated with the main table motor;
(*b*) those associated with the feed motor ;
(*c*) those associated with the tool relieving solenoids.

MAIN TABLE MOTOR CIRCUITS.

The table motor power circuit is shown in fig. 2. It will be seen that, apart from the pre-

sence of the reversing contactors, the arrangement is quite conventional. The motor field is excited at a constant voltage from a selenium rectifier (not shown on the diagram). The output voltage of the grid-controlled mercury arc rectifier, and therefore the planer table speed, is governed by varying the phase of the supply to the rectifier grids. Reversal is effected by changing over the reversing contactors and simultaneously retarding the phase of the grid supply. The rectifier then functions as an inverter and presents a back e.m.f. to the motor, which is now functioning as a generator. The inverter back e.m.f. is progressively reduced by advancing the phase of the grid supply, so that current is accepted from the motor which is consequently slowed down. By continuing to advance the phase of the rectifier grid supply the speed of the motor may be reduced to zero and then raised to any desired value in the reverse direction. In order that this phase change may take place automatically and at a controlled rate, the phase angle is made dependent on the current flowing in the motor armature, so that during reversal the motor braking and accelerating current remains practically constant.

During the cutting and return strokes of the planer table, it is necessary that the motor speed should remain substantially constant at a pre-set value, and on the cutting stroke it is important that the motor speed should not vary appreciably with variation of cutting load. This is achieved by making the phase angle of the grid supply dependent on rectifier output voltage. Fig. 3 is a block diagram illustrating the control system. It will be seen that the closed loop or servo system is used. The " voltage proportional to output voltage " is derived by means of a potentiometer across the output terminals of the rectifier and is opposed to the " voltage reference," which is a potential developed across a potentiometer. The difference of these two voltages, known as the " voltage error," is fed into an electronic amplifier whose output controls a static phase shifting network, the output of which, in turn, controls the rectifier via its grids.

The " voltage proportional to output current "

Fig. 1.—General view of the planer with its electronic control equipment. The power control cubicle and transformer are mounted on a platform above the planer, while the control desk can be seen on the right.

is derived from a D.C. current transformer connected in series with the rectifier output. This is opposed to the "current reference" and controls the rectifier in a manner similar to the voltage control except that, by a special arrangement in the amplifier, the current-regulating system is made non-operative until a predetermined value of current has been reached.

GRID CONTROL.

Fig. 4 shows diagrammatically the connections of the phase shifting network. A full explanation of the theoretical principles is beyond the scope of this article. It will be seen that the input to the network, which is derived from the A.C. mains supplying the rectifier power transformer,

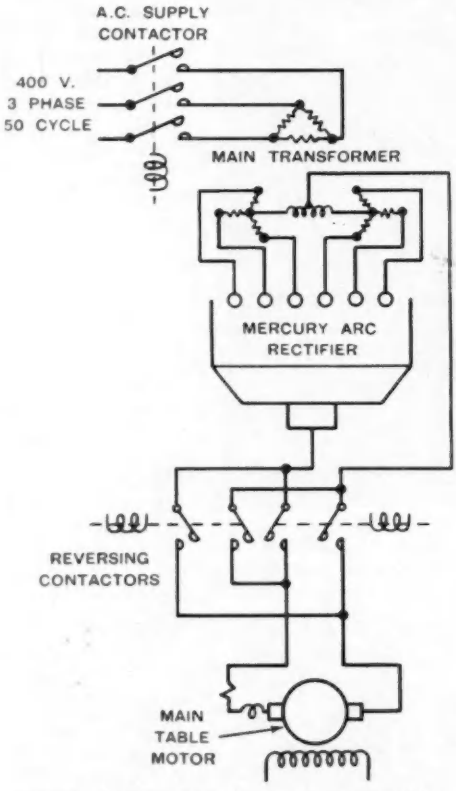


Fig. 2.—Diagram of table motor power circuit.

is passed through a phase pre-setting autotransformer and two D.C. saturable reactors to the primary winding of the saturated core grid transformer. Immediately after the D.C. saturable reactor (1) a three-phase condenser bank and a three-phase saturated core A.C. reactor are connected across the A.C. lines. Immediately after the D.C. saturable reactor (2) a three-phase condenser is connected across the lines. The arrangement as shown is purely diagrammatic; in fact, each of the D.C. saturable reactors has six windings, two per line, and one D.C. controlling winding. The saturated core A.C. reactor and the saturated core grid

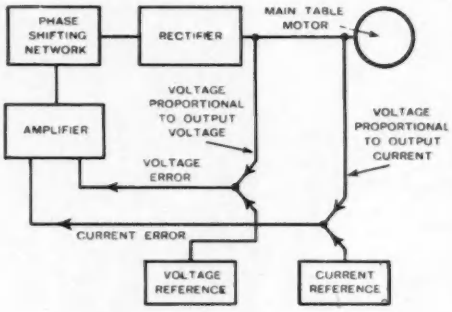


Fig. 3.—Block diagram of control system.

transformer are identical, except for the fact that secondary windings are omitted from the reactor. Each has six single phase cores and the primary windings are connected in a complex zigzag, giving compensation of all harmonics of magnetising current up to the eleventh.

The form of the grid voltage wave is steeply rising and has a duration of approximately 60°, thus giving precise control of the rectifier under all conditions. The peak voltage and form of the grid voltage wave do not change appreciably with variation of phase. Control of the phase of the output is effected by control of the D.C. saturating current. By varying this current from 0 to 150 milliamperes, the phase of the grid voltage varies from −180° to 0°. Thus it will be seen that complete control of the rectifier output voltage is obtainable by control of the D.C. saturating current, and the sense is that a decrease of saturating current gives a decrease of rectifier voltage (or increase of inverter voltage if the rectifier is at that instant functioning as an inverter). The main components of the phase shifting network may be seen in fig. 5.

SPEED CONTROL.

Fig. 6 is a diagrammatic representation of the amplifier and associated circuits. The amplifier is excited by the power units *b* and *c*. The main transformer neutral is connected to the common cathodes of valves V_1 and V_2. A

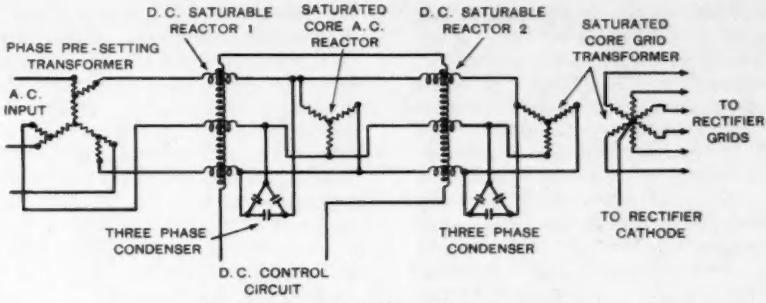


Fig. 4.—Diagram of phase shifting network.

fraction of the rectifier voltage is derived from the potentiometer P_6 and is opposed to the voltage drop across any one of the potentiometers P_1, P_2, P_3, P_4, which are excited by a source of D.C., a. These potentiometers act as the controllers of "Forward speed," "Ceiling speed," "Return speed" and "Inch speed" respectively. The difference of these two voltages, which is the "error," appears between grid and cathode of valve V_1. Ignoring for the present valve V_2, suppose that P_1 is in circuit, and that the voltage across P_1 is two or three volts greater than the voltage derived from P_6. Under these conditions the grid of the valve V_1 will be two or three volts negative relative to its cathode. The connections of valve V_3 are arranged so that its grid, which is connected to the anode of valve V_1, is also somewhat negative relative to its cathode. Therefore a current will flow in g which will be greater than zero, but less than the maximum which valve V_3 can pass. Now g is the diagrammatic representation of the two series connected saturating windings of the phase shifting network. Therefore a particular phase lag will exist and the rectifier output voltage will have a corresponding value. Since it is the rectifier output voltage which appears across P_6 it can readily be seen that only one value of this voltage can give a grid to cathode voltage on valve V_1, which will result in the required rectifier grid phase angle. Assuming that the voltage derived from P_1 is not changed, if for some reason the rectifier voltage rises, the grid of valve V_1 will become less negative and the current in its anode circuit will increase. This will increase the voltage drop across the anode load resistance f and decrease the drop across the valve. The grid of valve V_3 will therefore become more negative and its anode current will be reduced. Thus the saturating current in the phase shifting network will be reduced and the rectifier D.C. output voltage reduced. In the same way, it will be seen that if the rectifier output

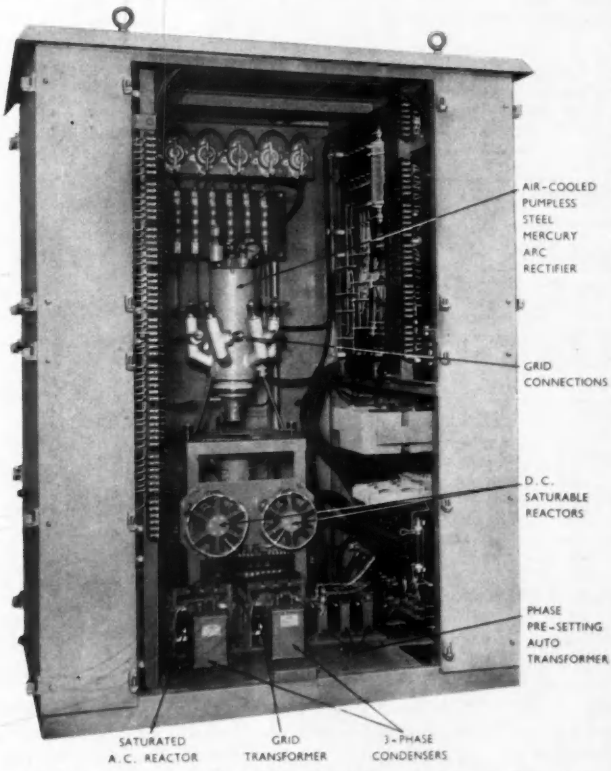


Fig. 5.—Power control cubicle, which houses the rectifier, phase shifting network, etc.

voltage tends to fall, the system will tend to bring it back to its previous value. Further, if the setting of the control potentiometer P_1 is altered the grid potential of V_1 will be changed in such a sense as to compel the rectifier output voltage to change to a new value corresponding to the new setting of P_1. Thus, irrespective of the load which the planer driving motor may throw on to the rectifier, the latter will deliver a practically constant voltage pre-set to a desired value. Each of the potentiometers P_1, P_2, P_3 is switched in by a relay at the appropriate part of the cycle of the planer table, while P_4 is switched in by the inch push buttons.

ACCELERATION CONTROL.

Valve V_2 which gives the overriding current control must now be considered. The grid of valve V_2 is excited by a potential which is equal to the difference between a voltage proportional to the load current flowing in the rectifier and a selected voltage derived from the potentiometer P_5. The rectifier load current flows through current, a D.C. voltage appears across the load h which is proportional to the current flowing in the main rectifier circuit. Compared with a shunt, the D.C. current transformer has the advantages of providing circuit isolation and of giving, when needed, a large voltage output with only a small energy dissipation. If the A.C. exciting voltage varies, the output varies, but to a much lesser extent, so that this error can usually be ignored.

The operation of the overriding current control will now be considered. The potential derived from P_5, in the absence of any potential across h, biases the grid of the valve V_2 negatively. This bias is arranged to be several times that necessary just to prevent this valve from carrying any current. Therefore valve V_2 will remain inoperative until the voltage across h rises to a considerable value. Assuming that a progressively increasing load is applied to the planer motor, i.e. to the main rectifier, the current through d will rise and so will the voltage across h. The bias on the grid of valve V_2

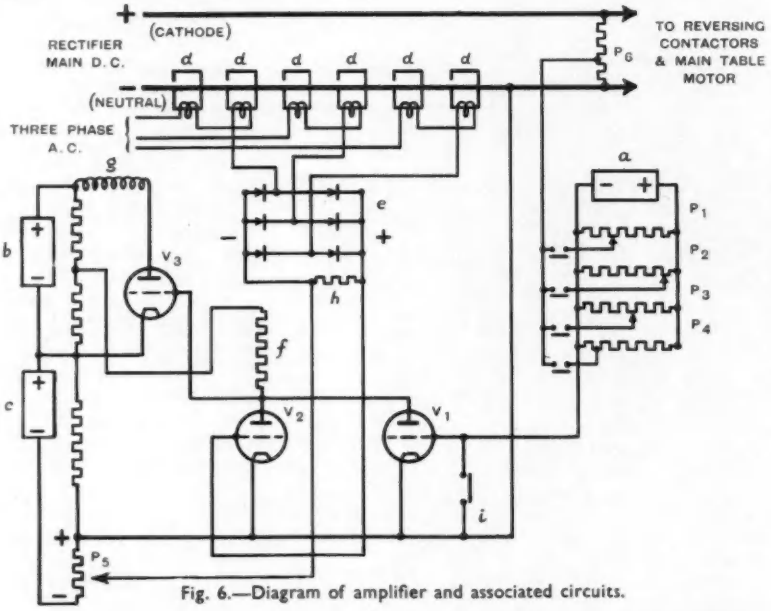


Fig. 6.—Diagram of amplifier and associated circuits.

a D.C. current transformer comprising six small cores d threaded on to the negative bar. Each core has an A.C. winding ; these are connected in pairs in series opposition. The system is excited with three phase A.C. and the output rectified by the three phase bridge connected selenium rectifier e. As a result of the saturation of the six small cores d by the D.C. load

will fall until it begins to conduct. When t happens the current in f will increase and the grid of valve V_3 will become more negative. This, as described before, will retard the phase of the rectifier grid supply and cause the output voltage to fall. Thus the rise of current will be checked. If the load is still increased, the valve V_2 will continue to retard the phase until ult-

imately the motor will stall with controlled current flowing in its armature. In the meantime the fall in voltage derived from P_6 without any corresponding fall in voltage derived from a speed control potentiometer, say, P_1 will have caused the grid of valve V_1 to become strongly negative and so valve V_1 will have become cut off. Thus control has passed automatically from

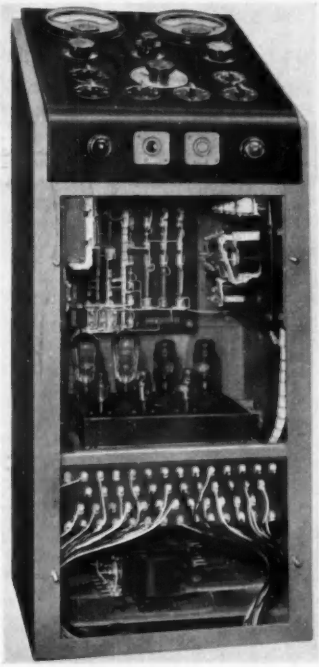


Fig. 7.—Control desk with front cover removed to show the amplifier.

valve V_1 to valve V_2. If now the load is removed from the motor it will accelerate with practically constant current flowing in its armature until the voltage derived from P_6 once again balances the voltage derived from P_1 and valve V_1 begins to conduct. The speed will then cease to rise since conduction through V_1 will tend to make the grid of V_3 more negative and so check the advance of the rectifier grid phase which was occurring during acceleration. The load will now fall off and so the potential across h will fall and the valve V_2 will once more be biased beyond cut off.

Since the overriding current control makes it possible to stall the motor without injury, it will be clear that it can provide a safe means of starting the main motor. At first sight it would appear that all that is necessary is to pre-set the rectifier voltage to correspond with the desired speed and then close the main power circuit. The current would then rise in the motor armature until valve V_2 becomes conductive, at which level of current the motor would run up. In practice this results in some initial overshooting of the current due to the fact that two very short time delays exist in the phase shifting network, and the rate of rise of current in the main motor armature is extremely high. To prevent this overshoot the relay contact i is provided, which is closed when the main armature circuit is open. When i is closed, valve V_1 is on full conduction and valve V_3 is cut off, so that the rectifier voltage is zero. Thus the armature contactors close on no load and the rate of rise of armature current is such that negligible overshooting occurs. In the same way, when the armature contactors are opened the relay i closes and removes the load from the circuit. Now relay i closes a small fraction of a second before the armature contactors open, so that the contactor opening occurs on no load and is arc-less. The amplifier is mounted in the control desk and may be seen in fig. 7.

REVERSAL CONTROL.

Reversal at constant current occurs automatically when the armature contactors are changed over, the relay i being closed during the change-over period. In order to follow the theory of operation, the following facts must be kept in mind.

1. When a rectifier is to function as an inverter, the polarity of the motor, which will now behave as a generator, must be reversed.
2. When a rectifier is to function as an inverter, the grid supply phase angle must be retarded by not less than 90°.
3. An inverter cannot provide power, but exerts a back e.m.f. against the generator, and accepts power.
4. An increase of retardation of inverter grid phase angle *increases* the inverter back e.m.f.
5. An increase in inverter back e.m.f. causes a *decrease* of current provided that the generator e.m.f. remains constant.

The sequence of reversal is as follows :—

1. Table limit switch operates.
2. Relay i closes. This retards the grid phase nearly 180°.
3. The main armature contactors open.
4. The main armature contactors for the reverse direction close.
5. Relay i opens.

The closing of relay *i*, which retards the grid phase nearly 180°, produces a back e.m.f. greater than the maximum motor e.m.f., even at maximum speed, so that when the reverse-direction contactors close no current flows. When relay *i* opens, the grid phase is advanced and current begins to flow in the inverter. This current grows until valve V_2 becomes conductive. This checks the advance of grid phase, and checks the fall of inverter back e.m.f., thus preventing any further rise of current. In this way the motor is braked regeneratively and slows down on constant current, since any tendency of the current to fall will tend to increase the negative potential of the grid of the valve V_2 and so advance the rectifier grid phase, thus tending to increase the current. The motor comes to rest and runs up in the reverse direction without pause until the potential derived from P_6 balances the potential derived from any one of P_1, P_2, P_3, P_4. The polarities indicated on the main bars in fig. 6 apply only during rectification. During the retardation period of reversal the polarities are reversed, so that the potential derived from P_6 *adds* to the potential derived from P_1, P_2, P_3 or P_4 and the two combine to make the grid of valve V_1 very negative, so that this valve is now non-conductive and plays no part in the reversal until the motor is up to speed in the reverse direction.

Fig. 8.—Top of control desk, showing the position of the various controls.
1. Driving motor armature current control potentiometer P_5. 2. Forward speed control potentiometer P_1. 3. Acceleration or ceiling speed control potentiometer P_2. 4. Return speed control potentiometer P_3. 5. Acceleration cancellation switch. 6. Rotary stud feed selector switch. 7. Return speed switch. 8, 9, 10, 11. Tool solenoid switches.

Hence it will be seen that reversal takes place at controlled constant current with no initial peak, thus reducing mechanical stresses, and that the contactors operate on no load. This represents an advantage over the normal Ward-Leonard system where the reversal current is very peaked and the contactors have to operate in highly-inductive field circuits. Further, due to the very precise control, the limit of table travel is particularly consistent.

DUAL SPEED CONTROL.

In some planing operations it is desirable to be able to increase the speed of the table for part of its travel. This is frequently done when planing two widely separated surfaces.

A special limit switch operated by the table motion provides the signals for "Increase speed" or "Accelerate" and reduction of speed to normal. To increase speed, all that is needed is to change from the normal cutting speed control potentiometer P_1 to another "ceiling speed" potentiometer P_2 pre-set for a higher speed. The valve V_1 is immediately biased to cut off, the current rises in the motor very rapidly to the maximum pre-set value and the table accelerates to the new speed. At the termination of the high-speed portion of the stroke the potentiometers are changed back and dynamic braking (not shown) applied to return the table to the cutting speed. The extremely rapid rate of response of this feature is most impressive, the table appears to "leap" forward, and, in fact, reaches ceiling speed in a few inches of travel. This fact makes it economic to use this feature for much shorter strokes than has hitherto been worth while.

In the foregoing description certain time lags have been mentioned. While these lags are quite real, it must be appreciated that they are very short compared with the more familiar time lags which are present in a generator field circuit. In fact, the time taken for the grid phase to retard 180° when relay *i* is closed is of the order of $\frac{1}{80}$ second.

A further advantage of the overriding current control is that the operator may move any of the potentiometers P_1, P_2, P_3 at any speed, when the planer is working, without imposing any electrical or mechanical stresses on the equipment. The current limit potentiometer P_5 is also under control of the operator, so that he can adjust the rapidity of reversal to suit the work in hand.

DYNAMIC BRAKING.

Dynamic braking (not shown in the diagrams) is used to give a quick stop when the normal stop button is pressed. A solenoid brake, closed

by a spring and opened electrically, is mounted on the end of the main motor shaft. This brake is de-energised and so stops the machine if the table overshoots its normal limit switch or if one of the emergency stop buttons is pressed.

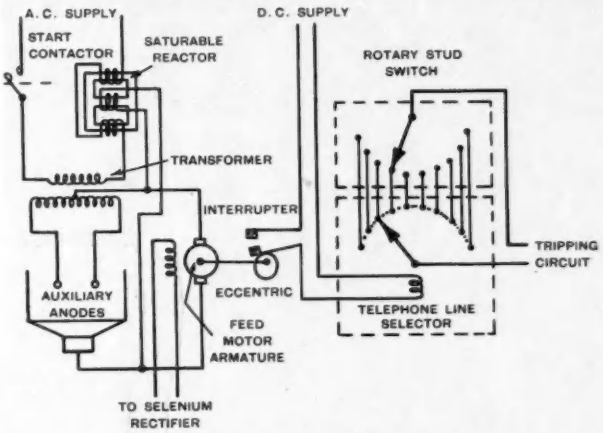


Fig. 9.—Diagram of feed motor circuit.

Simultaneously with the application of the brake the main incoming A.C. breaker is tripped.

The position on the control desk of the various controls which have been mentioned in the foregoing description and of those to be referred to subsequently is shown in fig. 8.

FEED MOTOR SYSTEM.

The feed motor is provided for the purpose of moving the tool holders along the slides of the planer a predetermined distance, once for each complete cycle of the table. The motor also provides the traverse motion of the tool holders used when setting up. In order that the feed shall be accurate and consistent it is necessary that the motor armature shall make an accurately counted number of revolutions each time it operates, and in order that the operator can adjust the distance of feed in accordance with the nature of the work, he must be able to pre-set the number of revolutions which the motor will make. The tool holder feed motion occurs while the table is reversing from its " return " stroke to its " cut " stroke, and is initiated by the table limit switch which also initiates the reversal.

The feed motor armature is supplied through two non-grid controlled auxiliary anodes in the rectifier, used also to supply the main table motor. The circuit arrangement is shown in fig. 9.

A saturable reactor is connected in series with the primary winding of a single phase transformer which excites the auxiliary anodes. The D.C. winding of the saturable reactor is connected across the motor armature. The reactor is so designed that, when the motor is stationary, full load current will flow through its armature when the start contactor is closed. As the motor runs up its back e.m.f. rises, which progressively saturates the reactor core until its impedance is negligible. Thus the motor runs up on practically constant current by merely closing the start contactor.

The number of revolutions is counted by mounting an eccentric on the motor shaft. An interrupter operated by the eccentric " notches round " a telephone line selector. Certain of the fixed contacts on the selector are connected to the studs of a ten-way rotary switch. When the rotor of the selector connects with the fixed contact which is joined to the pre-selected stud on the rotary switch, the tripping circuit is completed. The motor is stopped by opening the start contactor and applying dynamic braking (not shown).

When the cycle is complete the line selector is reset to the zero position by a method similar to that used in automatic telephone exchanges. When the " traverse " button is pressed the motor starts as described above, but the counting circuit is not connected, so that the motor runs continuously until the button is released. For the convenience of the operator it is arranged that when the " traverse " button is pressed the motor runs in the reverse direction from its rotation when operating the feed.

Of course, if desired, a stud switch with a larger number of studs could have been used, but the planer had already been fitted with a two-speed gear-box in the feed system, so that actually twenty feeds are obtainable varying from $\frac{1}{64}$ inch to $1\frac{1}{2}$ inches.

TOOL RELIEVING SOLENOIDS.

The tool relieving solenoids, provided to lift the tool clear of the work during the return stroke of the table, are excited from a selenium rectifier. There are four tool holders, each fitted with a solenoid, and the operator is provided with a switch for each solenoid. The solenoids are switched in and out at the correct points in the cycle of motion of the table by auxiliary contacts on the main table motor reversing contactors.

CONCLUSION.

Finally, it may be said that in the servo-electronically controlled planer the anticipated advantages have been fully realised and its reliability proved after several months' operation in the main engineering shop at Witton Works, Birmingham, by an operator having no previous experience of electronic control systems.

The machine may justly be claimed in every respect to represent a real advance in the art of machine tool electrification. It will be appreciated that the importance of this development is not limited to machine tool work, since it represents a highly successful system applicable to many other forms of reversible drive, providing accurately controlled running speed in both directions, stepless speed adjustment, controlled reversal current, and therefore reversal torque, requiring no rotating plant and therefore no heavy foundations, and having a high efficiency.

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By J. W. Ryde (Research Laboratories).
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